APPENDIX A
DESIGN CALCULATIONS

Calculations of Groundwater Concentrations During Pumping and Through Treatment
Quebecor Printing Atglen Inc., Atglen, Pennsylvania

1. Estimated Groundwater Concentrations - Railroad Siding Area

	Static Groundwater Conditions							Pumping Condition* Concentrations	Concentrations After Volatilization**
	MW-10	MW-20	S-1	S-4	RW-3	RW-4	AVERAGE		
Benzene (ug/l)	64	3	0	25	19	21	22	17	12
Toluene (ug/l)	618	176	0	60	18	110	164	123	92
Ethylbenzene (ug/l)	271,000	5,450	0	1,540	1,860	7,340	47,865	35,899	26,924
Xylenes (ug/l)	3,460	824	0	138	440	428	882	661	496
BTEX (ug/l)	275,142	6,453	0	1,763	2,337	7,899	48,932	36,699	27,524
Tetrachloroethene (PCE) - (ug/l)	0	0	0	0	2.53	0	0	0	0
Bis (2-ethylhexyl)phthalate (ug/l)	0	0	0	0	0	0	0	0	0

*Concentrations during pumping conditions were estimated assuming a 25% reduction in concentrations.

**An additional 25% decrease in concentrations was assumed due to the volatilization that occurs due to the turbulent mixing during HVTPE.

Static concentrations are from October 21, 1997 sampling event.

All non-detectable sampling results have been estimated to equal zero for averaging purposes.

2. Estimated Groundwater Concentrations - Line Leak Area

	Static Groundwater Conditions					Pumping Condition* Concentrations	Concentrations After Volatilization**
	MW-22	MW-21A	Sump-1	TH-1	AVERAGE		
Benzene (ug/l)	0	2	0	0	1	0	0
Toluene (ug/l)	2	1,680	134	12	457	343	257
Ethylbenzene (ug/l)	0.9	1,880	34	0	479	359	269
Xylenes (ug/l)	436	9,920	111	2	2,617	1,963	1,472
BTEX (ug/l)	438.9	13,482	279	14	3,553	2,665	1,999
Tetrachloroethene (PCE) - (ug/l)	0	16.9	0.0	0.0	4	3	2
Bis (2-ethylhexyl)phthalate (ug/l)	0	0	0	0	0	0	0

*Concentrations during pumping conditions were estimated assuming a 25% reduction in concentrations.

**An additional 25% decrease in concentrations was assumed due to the volatilization that occurs due to the turbulent mixing during HVTPE.

Static concentrations at MW-22 and MW-21A are from October 21, 1997 sampling event. Static concentrations at Sump 1 and TH-1 are from January 14, 1998 sampling event.

All non-detectable sampling results have been estimated to equal zero for averaging purposes.

3. Estimated Groundwater Concentrations - Tank Field Area

	Static Groundwater Conditions				Post Excavation Concentrations***	Pumping Condition* Concentrations	Concentrations After Volatilization**
	MW-3	RW-1	MW-2	AVERAGE			
Benzene (ug/l)	1	0	0	0	0	0	0
Toluene (ug/l)	0.6	6,030	0	2,010	1,206	905	678
Ethylbenzene (ug/l)	0.8	0	0	0	0	0	0
Xylenes (ug/l)	4	3,160	0	1,055	633	475	356
BTEX (ug/l)	6.4	9,190	0	3,065	1,839	1,379	1,035
Tetrachloroethene (PCE) - (ug/l)	0.0	0	0	0	0	0	0
Bis (2-ethylhexyl)phthalate (ug/l)	0	0	0	0	0	0	0

*Concentrations during pumping conditions were estimated assuming a 25% reduction in concentrations.

**An additional 25% decrease in concentrations was assumed due to the volatilization that occurs due to the turbulent mixing during HVTPE.

*** Assuming that the majority of the solvent-impacted soil is removed during excavation/tank removal activities, it has been estimated that dissolved concentrations should decrease 40%.

Static concentrations at MW-2 and MW-3 are from October 21, 1997 sampling event. Static concentration at RW-1 is from January 8, 1998 sampling event.

All non-detectable sampling results have been estimated to equal zero for averaging purposes.

4. Estimated Groundwater Concentrations Through The Groundwater Treatment System

	Groundwater Concentration Data						
	Railroad Siding Area	Line Leak Area	Tank Field Area	Combined System Influent (Air Stripper Influent)	Air Stripper Effluent (Primary GAC Inflnt.)	Primary GAC Effluent (Secondary GAC Inflnt.)	Secondary GAC Effluent (Sewer Discharge)
Number of Recovery Wells Connected	15	10	6	31	31	31	31
Number of Recovery Wells Operating	10	7	3	20	20	20	20
Ave. GW Flow Rate Per Well (gpm)	0.41	0.64	0.86	NA	NA	NA	NA
Ave GW Flow Rate For Area (gpm)	4.10	4.48	2.58	11.16	11.16	11.16	11.16
Benzene (ug/l)	12	0	0	5	0.05	0.00	0.00
Toluene (ug/l)	92	257	678	294	2.94	0.03	0.00
Ethylbenzene (ug/l)	26,924	269	0	10,000	100.00	1.00	0.01
Xylenes (ug/l)	496	1,472	356	855	8.55	0.09	0.00
BTEX (ug/l)	27,524	1,999	1,035	11,154	111.54	1.12	0.01
Tetrachloroethene (PCE) - (ug/l)	0	2	0	1.0	0.01	0.00	0.00
Bis (2-ethylhexyl)phthalate (ug/l)	0	0	0	0	0.00	0.00	0.00

The combined system influent concentrations were derived by calculating the flow-weighed average concentration from the the influent flow streams (railroad siding, line leak, and tank field areas)

A 99% air stripper removal efficiency was utilized to determine post stripper (pre-carbon) concentrations.

A 99% liquid-phase carbon removal efficiency was utilized through each GAC (primary and secondary) to determine post-carbon (sewer discharge) concentrations.

5. Estimated Air Stripper Off-Gas Vapor Concentrations

Constituent	Air Stripper Influent GW Concentrations (ug/l)	Air Stripper Off-Gas Loading (pre VGAC-7) (lb/day)	Vapor GAC Carbon Usage Rate (lb - GAC/day)	Vapor GAC Effluent/Discharge to Atmosphere (lb/day)
Benzene (ug/l)	4.69	0.00	0.00	0.00
Toluene (ug/l)	293.86	0.04	0.20	0.00
Ethylbenzene (ug/l)	9,999.58	1.34	6.71	0.01
Xylenes (ug/l)	855.48	0.11	0.57	0.00
BTEX (ug/l)	11,153.60	1.50	7.48	0.01
Tetrachloroethene (PCE) - (ug/l)	1.04	0.00	0.00	0.00
Bis (2-ethylhexyl)phthalate (ug/l)	0.00	0.00	0.00	0.00
TOTAL	**NA**	**2.99**	**14.96**	**0.03**

A 99% removal efficiency was estimated through the GAC unit.

A 20% BTEX adsorption capacity was used to calculate the GAC usage through the vapor-phase GAC unit.

For estimating purposes, the air stripper off-gas loading assumes 100% transfer of BTEX from the dissolved-phase.

Off-gas loading (lb/day) =

concentration(ug/l)	3.785 liters	2.205 lb	# gallons/minute	1440 minutes
	gallon	10^9 ug		day

GES

1. Estimated Vapor Extraction Parameters From Railroad Siding Area (From Historical Pilot Test Data)

Date	Extraction Well	Ave. Applied Vac. (i.w.)	Ave. BTEX Conc. (ppmv)	Ave. Vapor Flow Rate (acfm)	Ave. Vapor Flow Rate (scfm)	Ave. Groundwater Recovery Rate (gpm)
5/4/94	RW-2	209	16.2	55	27	0.44
5/5/94	MW-10	209	283	27	13	0.66
AVERAGE DURING TESTING		209	150	41	20	0.55
EXPECTED LONG-TERM CONDITIONS*		209	150	31	15	0.41

*The long-term groundwater recovery rate is expected to decrease the initial groundwater recovery rate by 25%.
*The soil vapor recovery rate observed during pilot test activities is expected to decrease by 25% due to the close proximity of extraction wells (overlapping influence areas).
The average BTEX concentration was estimated from OVM readings obtained during pilot testing activities.
See Page 5 for scfm/acfm conversions.

2. Estimated Vapor Extraction Parameters From Line Leak Area (From Historical Pilot Test Data)

Date	Extraction Well	Ave. Applied Vac. (i.w.)	Ave. BTEX Conc. (ppmv)	Ave. Vapor Flow Rate (acfm)	Ave. Vapor Flow Rate (scfm)	Ave. Groundwater Recovery Rate (gpm)
5/4/94	RW-2*	209	16.2	55	27	0.44
5/5/94	MW-10*	209	283	27	13	0.66
5/27/94	MW-1E**	194	570	41	21	1.15
5/27/94	MW-3**	183	570	18	10	1.15
AVERAGE DURING TESTING		199	360	35	18	0.85
EXPECTED LONG-TERM CONDITIONS***		199	360	26	13	0.64

Note: Since TPHVE pilot tests have not been conducted in the Line Leak Area, parameters obtained from testing in the Railroad Siding and Tankl Field Areas were averaged in order to estimate Line Leak Area parameters.
* - Railroad Siding Area Well. ** - Tank Field Area Well.
***The long-term groundwater recovery rate is expected to decrease the initial groundwater recovery rate by 25%.
***The soil vapor recovery rate observed during pilot test activities is expected to decrease by 25% due to the close proximity of extraction wells (overlapping influence areas).
The average BTEX concentration was estimated from OVM readings obtained during pilot testing activities.
See Page 5 for scfm/acfm conversions.

3. Estimated Vapor Extraction Parameters From Tank Field Area (From Historical Pilot Test Data)

Date	Extraction Well	Ave. Applied Vac. (i.w.)	Ave. BTEX Conc. (ppmv)	Ave. Vapor Flow Rate (acfm)	Ave. Vapor Flow Rate (scfm)	Ave. Groundwater Recovery Rate (gpm)
5/27/94	MW-1E	194	570	41	21	1.15
5/27/94	MW-3	183	570	18	10	1.15
AVERAGE DURING TESTING		189	570	30	16	1.15
EXPECTED LONG-TERM CONDITIONS***		189	570	22	12	0.86

***The long-term groundwater recovery rate is expected to decrease the initial groundwater recovery rate by 25%.
***The soil vapor recovery rate observed during pilot test activities is expected to decrease by 25% due to the close proximity of extraction wells (overlapping influence areas).
The average BTEX concentration was estimated from OVM readings obtained during pilot testing activities.
See Page 5 for scfm/acfm conversions.

1. Estimated Vapor Extraction Parameters To Three Liquid-Ring Pump Skids

Liquid Ring Pump Skid	Area	Recovery Wells	# of Wells Connected	Ave. # of Wells Operating	Ave. Flow Rate/Well (scfm)	Total Flow Rate (scfm)	Ave. BTEX Conc. (ppmv)*
LRP-1	Railroad Siding	MW-10, RW-5, RW-6, RW-3, RW-4, RW-10, RW-12, RW-13	8	6	15	90	150
LRP-2	Railroad Siding	RW-7, RW-8, RW-9, RW-11, RW-2, S-1, S-3	7	4	15	60	150
	Tank Field Area	RW-24, RW-25, RW-26, RW-27, RW-28, and RW-29	6	3	12	36	570
LRP-3	Line Leak Area	RW-14, RW-15, RW-17, RW-19, RW-16, RW-18, RW-20, RW-21, RW-22, RW-23	10	7	13	91	360
		TOTAL	31	20		277	

* - The Average BTEX concentration is expected to decrease asymptotically over time.

Vapor concentration as ug/L = $\frac{\text{conc. (ppmv)}}{} \left| \frac{\text{molecular weight}}{\text{24.05 L/mol}} \right.$ (assume C4-C10 molecular weight = 100)

Vapor-phase hydrocarbon loading (lb/day) = $\frac{\text{conc. (ug/liter)}}{} \left| \frac{\text{flow rate (ft}^3\text{/m)}}{} \right| \frac{\text{1 mg}}{\text{1,000 ug}} \left| \frac{\text{1 pound}}{\text{454,000 mg}} \right| \frac{\text{1,000 liter}}{\text{m}^3} \left| \frac{\text{0.0283 m}^3}{\text{ft}^3} \right| \frac{\text{1440 min.}}{\text{day}}$

2. Estimated Vapor Extraction Parameters Through Vapor Treatment System

Liquid Ring Pump Skid	Area	Primary/Secondary GAC Designations	Total Flow Rate (scfm)	Primary GAC Influent			Primary GAC Effluent/Secondary GAC Influent			Secondary GAC Effluent	
				Ave. BTEX Conc. (ppmv)*	BTEX Loading (lb/day)	Primary GAC Usage (lb/day)	Ave. BTEX Conc. (ppmv)*	BTEX Loading (lb/day)	Secondary GAC Usage (lb/day)	Ave. BTEX Conc. (ppmv)*	BTEX Loading (lb/day)
LRP-1	Railroad Siding	VGAC-1, VGAC-2	90	150	5.0	25.2	1.5	0.05	0.3	0.02	0.001
LRP-2	Railroad Siding/Tank Field	VGAC-3, VGAC-4	96	330	11.8	59.1	3.3	0.12	0.6	0.03	0.001
LRP-3	Line Leak Area	VGAC-5, VGAC-6	91	360	12.2	61.1	3.6	0.12	0.6	0.04	0.001
		TOTAL	277		29.1	145.4		0.29	1.5		0.003

* - The Average BTEX concentration is expected to decrease asymptotically over time, resulting in decreasing recovery rates and decreasing GAC usage.
Each LRP skid is manifolded to two vapor-phase carbon units.
A 99% removal efficiency was estimated through each primary and secondary GAC.
A 20% BTEX adsorption capacity was used to calculate the GAC usage.

Calculations of scfm/acfm Conversions
Quebecor Printing Atglen Inc., Atglen, Pennsylvania

acfm to scfm

air flow (acfm)	pressure (psig)	temperature (degrees F)	Calculated air flow rate (scfm)
55	-7.5	60	27
27	-7.5	60	13
41	-7.5	60	20
41	-7.0	60	21
18	-6.6	60	10
35	-7.2	60	18
26	-7.2	60	13

scfm to acfm

air flow (scfm)	pressure (psig)	temperature (degrees F)	Calculated air flow rate (acfm)
90	-10.3	50	296
96	-10.3	50	316
91	-10.3	50	299

$$\text{air flow (scfm)} = \text{air flow (acfm)} \times \frac{14.7 + \text{Pressure (psig)}}{14.7} \times \frac{520}{460 + \text{Temp. (deg F)}}$$

$$\text{air flow (acfm)} = \text{air flow (scfm)} \times \frac{14.7}{14.7 + \text{Pressure (psig)}} \times \frac{460 + \text{Temp. (deg F)}}{520}$$

27.7 iw = 1 psig
2.036 "Hg = 1 psi

APPENDIX B
HISTORICAL PILOT TEST AND SLUG TEST DATA

VAPOR EXTRACTION TESTS CONDUCTED 25 and 27 MAY 1994

CORRECTIVE MEASURES STUDY QUEBECOR PRINTING ATGLEN INC. ATGLEN, PA

BACKGROUND

As part of an ongoing Corrective Measures Study (CMS) at the Quebecor facility in Atglen, Pennsylvania, several tests employing high-vacuum extraction were conducted in the tankfield area to determine the feasibility of this technology for remediation and to determine if groundwater withdrawal can be enhanced by high-vacuum extraction. The initial test, completed on 25 May 1994, was performed by extracting vapors simultaneously from wells MW-1E and MW-3. Follow-up tests were performed on 27 May 1994 by extracting vapors individually from the same wells. Wells MW-1E and MW-3 were utilized as extraction wells because they are centrally-located in the tankfield area and their construction allowed installation of adaptors on the wellheads. The well-head adaptors were needed to maintain vacuum in the wells during pumping. Well and vapor monitoring point locations used during the tests are shown in Figure 1.

METHODOLOGY

A vapor extraction and treatment unit (VR unit) manufactured by Vapor Recovery Systems, Inc.® was used to conduct the tests. The VR unit is an internal combustion engine capable of extracting vapors from a designated vapor recovery point at a maximum design air flow rate of 250 cubic feet per minute; the unit is capable of producing a vacuum of up to 300 inches of water.

Vapors withdrawn from the extraction points are pulled back to the VR unit and destroyed in the internal combustion engine. If hydrocarbon concentrations are high enough, the recovered vapors can be used as the sole source of fuel to run the engine. The system is completely automated and will supply supplemental fuel (propane) when hydrocarbon concentrations in recovered vapors are not sufficient to run the system. The system is capable of removing up to 55 pounds per hour (lbs/hr) of hydrocarbons at a destruction rate of 99.97%.

Soil vacuum induced during the test was monitored with vacuum gauges at existing monitoring wells and temporary vapor monitoring points surrounding the extraction points. The temporary monitoring points were constructed by hand-driving a 1/2-inch diameter steel rod approximately 48 inches below grade. After the rod was removed, a 30-inch long, 1/4-inch diameter copper tube was inserted into the hole. A 1-inch diameter rubber stopper, which slides over the tube, was installed near the top of the copper tube. When the copper tube is inserted into the soil, the rubber stopper acts as a plug and a vacuum seal. Soil pressure and soil gas can also be monitored through this tube.

On Wednesday, 25 May 1994, a high-vacuum extraction pilot test was conducted simultaneously on monitoring wells MW-1E and MW-3 for 8 hours. Both vapor extraction wells were fitted with a specially-designed air-tight cap which allowed a suction tube to be inserted into the well below the water table. When the VR unit was activated, water was withdrawn from the well (by the suction tube) and directed to a knock-out tank. Once the well water was evacuated, the same suction tube was used to withdraw vapors from the surrounding soil. Each time the water column began to recharge in the well, vacuum (by the suction tube) removed the water from the well and continued to draw vapors from the soil. This method of vapor extraction effectively depresses the water column in the well throughout the test and maintains a maximum length of exposed well screen for soil vapor extraction.

Vacuum gauges were deployed on surrounding wells (MW-1, MW-2, MW-2E, MW-4, MW-5, MW-16, MW-18) and vapor monitoring points (VP-1 through VP-7) to monitor remote vacuum influence at each of these points. Separation distances (vapor monitoring point to nearest extraction well) ranged from 13 to 102 feet.

During the pilot test, vacuum readings, air flowrates, and exhaust temperatures at the VR unit were recorded every hour. The volume of water pumped from the extraction wells was also recorded. A Thermo Environmental Instruments® Model 580B photoionization organic vapor meter (OVM) was used to monitor influent volatile organic compounds (VOC) concentrations after the first and second hours of the tests. In addition, an explosimeter was used to monitor the lower explosive limit (LEL) of the influent air stream and an oxygen meter was used to monitor influent oxygen levels after the first and second hours of the pilot test. Induced vacuum was recorded hourly at the monitoring points. Pre-test and post-test depth to water levels were also recorded at the monitoring wells. The tabulated results from the test are included in Table 1.

On Friday, 27 May 1994, follow-up high-vacuum extraction tests were conducted on each extraction well (MW-1E and MW-3) individually. The follow-up tests were performed to check for vacuum "short circuits" in the extraction wells. A vacuum short-circuit exists when air leaks directly from the surface to the vapor extraction point via the well borehole (and associated pathways) so that air movement is not a function of natural soil permeability.

Vacuum readings, air flow rates, and exhaust temperatures at the VR unit were recorded every 30 minutes throughout the follow-up tests. Each extraction well was tested for a minimum of 1.5 hours. Vacuum gauges were deployed on MW-4, VP-2, VP-4, and VP-6. In addition, MW-3 was gauged during the test on MW-1E, and MW-1E and MW-16 were gauged during the test on MW-3. Separation distances for the MW-1E test ranged from 13 to 38 feet; separation distances for the MW-3 test ranged from 28 to 65 feet. Induced vacuums were recorded during the tests at the monitoring points. Follow-up tests results are presented in Table 2.

RESULTS

The results of the pilot test show that high-vacuum extraction had a measurable influence on the surrounding soils. Simultaneous high-vacuum on MW-1E and MW-3 induced a vacuum in monitoring points MW-4 (0.11 inches water after 8 hours) and VP-6 (0.58 inches water after 8 hours). During individual testing, high-vacuum on MW-1E induced vacuums in MW-3 (0.16 inches water after 1.5 hours) and VP-6 (0.10 inches water after 1.5 hours), and high-vacuum on MW-3 induced a vacuum in MW-4 (0.14 inches water after 1.5 hours). Induced vacuum was not observed at the other monitoring points. Vacuum short circuits may account for the absence of induced vacuum at VP-4 (located close to MW-1E) and other monitoring points.

Airflow through the VR unit during the pilot test ranged from 33 to 71 standard cubic feet per minute (scfm). Airflow (when full vacuum was established) ranged from 36 to 44 scfm during the individual test on MW-1E and from 9 to 18 scfm during the individual test on MW-3. The disparity between the air flow values from the individual extraction well tests suggests that the MW-1E test had vacuum short circuits and was not as tight as the vacuum on MW-3.

Influent vapor OVM readings taken after the first and second hour of the pilot test were 610 ppm and 530 ppm, respectively. LEL readings taken after the first and second hours of the pilot test were 11% and 13%, respectively. Influent oxygen concentrations were 18.8% (first hour) and 19.4% (second hour) during the pilot test.

A total of 1,101 gallons of water, or 2.29 gallons per minute (gpm), was pumped from the wells during the pilot test. Since the average combined flow rate from these two wells is approximately 1.0 gpm (estimated from well-purging data), the increase in flow is attributed to the influence of high-vacuum.

Results from the pilot test were used to calculate soil vapor permeability, vapor flow per length of extraction well screen, and vapor extraction well radius of influence. Based on induced vacuum recorded at vapor monitoring points VP-6 and MW-4, and flow volume and vacuum recorded at extraction well MW-1E (the nearest extraction well), calculated soil vapor permeabilities were 1.561 darcys at VP-6 and 1.718 darcys at MW-4. The extraction well flow rate value used in the calculations (47.125 scfm) was based on results from the combined and individual extraction well tests which indicated that flow from MW-1E was approximately 4.3 times that from MW-3. Using the calculated soil vapor permeability values, the radius of influence for MW-1E was calculated to be from 24.98 to 37.96 feet. Calculations used to determine the radius of influence are summarized in Table 1.

CONCLUSIONS

The results of the three high-vacuum extraction tests indicate that this technology is a technically feasible alternative for remediation at the site. The combined well high-vacuum extraction test (25 May 1994) and the individual extraction well follow-up tests (27 May 1994) produced measurable induced vacuums at surrounding vapor monitoring wells. Increased groundwater flow was recorded in the extraction wells during the combined high-vacuum extraction test. Individual follow-up tests suggest that some vacuum short circuits were present at extraction well MW-1E; however, vacuum in MW-1E was sufficient to produce induced vacuums at two vapor monitoring points.

Based on test results, the calculated radius of influence for vapor extraction points in the tank field area is between 24.98 and 37.96 feet. These values are within the range for cost-effective vapor extraction remediation system design.

TABLE 1
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

WELLS TESTED: MW-1E and MW-3

								MONITORING POINTS**	
								VP-6	MW-4
						DISTANCE (ft)*		25 ft.	38 ft.
EXHAUST TEMP. (degrees F)	ELAPSED TIME (hrs.)	VACUUM (inches H2O)	TOTAL LEL (%)	O2 (%)	CO2 (%)	OVM READING (ppm)	FLOW VOLUME (scfm)	INDUCED VACUUM (Inches H20)	INDUCED VACUUM (Inches H20)
–	START	–	–	–	–	–	–	0.00	0.00
789	1:00	153	13	18.8	–	610	49	0.10	0.41
751	2:00	162	11	19.4	–	530	54	0.11	0.08
690	3:00	175	–	–	–	–	59	0.11	0.20
678	4:00	181	–	–	–	–	54	0.11	0.32
677	5:00	181	–	–	–	–	55	0.10	0.26
622	6:00	196	–	–	–	–	58	0.11	0.22
645	7:00	195	–	–	–	–	60	0.11	0.40
593	8:00	197	–	–	–	–	58	0.11	0.58

LEL = lower explosive limit
OVM = organic vapor meter
O2 = oxygen
CO2 = carbon dioxide

ppm = parts per million
fpm = feet per minute
scfm = standard cubic feet per minute

VP = vapor point
MW = monitoring well
* distance to MW-1E (nearest extraction well)
** induced vacuums were not observed at other test monitoring points

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

	MW-1E	MW-4
Extraction Well Diameter –	2 inches	4 inches
Extraction Well Borehole Diameter –	8 inches	8 inches
Height of Vadose Zone Available for – Extraction or Depth to Water	10 feet	10 feet

PERMEABILITY (k) in darcys

Time/Well	VP-6	MW-4
1:00	1.558	1.714
2:00	1.586	1.740
3:00	1.550	1.701
4:00	1.349	1.482
5:00	1.374	1.508
6:00	1.279	1.404
7:00	1.334	1.466
8:00	1.269	1.396

$$k = \frac{1440 * Pw * Q * u * \ln(Re/Rw)}{19.88 * H * (Pe^2 - Pw^2)}$$

Where:
Q = volumetric flow (CFM) from extraction well
u = viscosity of air (0.018 centipoise)
Re = distance to observation well (feet)
Rw = borehole radius of extraction well (feet)
H = height of vadose zone extracted (feet)
Pe = pressure at observation well (PSI)
Pw = pressure at extraction well (PSI)

TABLE 1 (cont'd)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Calculations for determining vapor permeability (k) and radius of influence of SVE points using equations described by P.C. Johnson et al., Ground Water Monitoring Review, Spring 1990.

Determination of soil permeability (k) in darcys:

The governing equation is:

$$k = \frac{Q * u * \ln(Rw/Ro)}{H * pi * Pw[1-(Po/Pw)^2]}$$

where:

- Q = air flow at the extraction well in cm3/sec
- u = viscosity of air in centipoise (0.018 cp)
- Rw = borehole radius of extraction well in cm
- Ro = distance to observation well in cm
- H = height of unsaturated zone affected by applied vacuum in cm
- Pw = pressure at the extraction well in atmospheres
- Po = pressure at the observation well in atmospheres

The following data are the results of the 25 May 1994 SVE test for VP-6

Q =	47.125	CFM
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	25	feet
H =	10	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.11	inches-H2O

The following data are converted to units consistent with Johnson's equation

Q =	22240.523	cm3/sec
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	762.000	cm
H =	304.800	cm
Pw =	0.516	atmospheres
Po =	0.99973	atmospheres

The following data are the results of the 25 May 1994 SVE test for MW-4

Q =	47.125	CFM
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	38	feet
H =	10	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.58	inches-H2O

The following data are converted to units consistent with Johnson's equation

Q =	22240.523	cm3/sec
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	1158.240	cm
H =	304.800	cm
Pw =	0.516	atmospheres
Po =	0.99857	atmospheres

Given the above conditions, the permeability of the formation is:

k = 1.27 darcys (VP-6)

k = 1.40 darcys (MW-4)

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Determination of flow rate in CFM/ft:

The governing equation is:

$$Q/H = \frac{K * pi * Pw[1-(Po/Pw)^2]}{u * ln(Rw/Ro)}$$

where:
Q/H = air flow per foot of screen at the extraction well in CFM/ft
u = viscosity of air in centipoise (0.018 cp)
Rw = borehole radius of extraction well in cm
Ro = distance to observation well in cm
Pw = pressure at the extraction well in atmospheres
Po = pressure at the observation well in atmospheres

The following data are the results of the 25 May 1994 SVE test for VP-6

K =	1.27	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	25	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.11	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.271	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	762.000	cm
Pw =	0.516	atmospheres
Po =	0.9997	atmospheres

Given the above conditions, the permeability of the formation is:

Q/H =	4.71	CFM/ft
Depth to Water (H) feet =	10	feet
Flow per Vapor Point is:	47.1	CFM

The following data are the results of the 25 May 1994 SVE test for MW-4

K =	1.40	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	38	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.58	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.398	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	1158.240	cm
Pw =	0.516	atmospheres
Po =	0.9986	atmospheres

Q/H =	4.71	CFM/ft
Depth to Water (H) feet =	10	feet
Flow per Vapor Point is:	47.1	CFM

GES

TABLE 1 (cont'd)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Determination of radius of influence in feet:

The governing equation is:

$$k = \frac{Q/H * u * \ln(Rw/Ri)}{pi * Pw[1-(Patm/Pw)^2]}$$

Solving for Ri:

$$Ri = Rw * EXP(-B)$$

where:

$$B = \frac{k * pi * Pw[1-(Patm/Pw)^2]}{Q/H * u}$$

Q/H = Vapor flow per unit length of screen (CFM/ft)

The following data are the expected operating conditions of the SVE system based on data from VP-6

Q/H =	4.71 CFM/ft
u =	0.018 Centipoise
Rw =	0.333 feet
k =	1.27 darcy
Pw =	197 inches-H2O
Po =	0.11 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.968 cm3/sec
u =	0.018 Centipoise
Rw =	10.150 cm
k =	1.27 darcy
Pw =	0.516 atmospheres
Po =	0.99973 atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-1E) is:

Ri = 24.98 feet

The following data are the expected operating conditions of the SVE system based on data from MW-4

Q/H =	4.71 CFM/ft
u =	0.018 Centipoise
Rw =	0.333 feet
k =	1.40 darcy
Pw =	197 inches-H2O
Po =	0.58 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.968 cm3/sec
u =	0.018 Centipoise
Rw =	10.150 cm
k =	1.40 darcy
Pw =	0.516 atmospheres
Po =	0.99857 atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-1E) is:

Ri = 37.96 feet

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	5.883075	179.316126	V(r16) =	0.192633514	1.92
r17 =	6.253080	190.593878	V(r17) =	0.180002485	2.06
r18 =	6.623085	201.871631	V(r18) =	0.168871122	2.19
r19 =	6.993090	213.149383	V(r19) =	0.158990633	2.33
r20 =	7.733100	235.704888	V(r20) =	0.142233313	2.60
r21 =	9.459790	288.334399	V(r21) =	0.113861978	15.16
r22 =	11.186480	340.963910	V(r22) =	0.094684954	18.24
r23 =	12.913170	393.593422	V(r23) =	0.080889511	21.35
r24 =	14.639860	446.222933	V(r24) =	0.070507253	24.49
r25 =	16.366550	498.852444	V(r25) =	0.062421612	27.66
r26 =	18.093240	551.481955	V(r26) =	0.055953110	30.86
r27 =	19.819930	604.111466	V(r27) =	0.050665076	34.08
r28 =	21.546620	656.740978	V(r28) =	0.046264359	37.32
r29 =	23.273310	709.370489	V(r29) =	0.042547004	40.58
r30 =	25.000000	762.000000	V(r30) =	0.039366818	43.86

delX1 (r2 to r19) = 0.370005 feet — Time = 304.70 seconds
delX2(r20 to r30) = 1.726690 feet — 5.30 minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well MW-1E

Time = 5.30 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Estimated travel time from the boundary of the influence to extraction well MW-1E

$$V(r) = \frac{-K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.333000	10.149840	---	---	---
r2 =	0.703005	21.427592	V(r2) =	2.232600321	0.17
r3 =	1.073010	32.705345	V(r3) =	1.344998139	0.28
r4 =	1.443015	43.983097	V(r4) =	0.950026937	0.39
r5 =	1.813020	55.260850	V(r5) =	0.729203169	0.51
r6 =	2.183025	66.538602	V(r6) =	0.589069467	0.63
r7 =	2.553030	77.816354	V(r7) =	0.492633450	0.75
r8 =	2.923035	89.094107	V(r8) =	0.422415646	0.88
r9 =	3.293040	100.371859	V(r9) =	0.369116199	1.00
r10 =	3.663045	111.649612	V(r10) =	0.327345235	1.13
r11 =	4.033050	122.927364	V(r11) =	0.293769848	1.26
r12 =	4.403055	134.205116	V(r12) =	0.266221533	1.39
r13 =	4.773060	145.482869	V(r13) =	0.243230274	1.52
r14 =	5.143065	156.760621	V(r14) =	0.223765263	1.65
r15 =	5.513070	168.038374	V(r15) =	0.207082870	1.79

Time = 13.34 seconds
0.22 minutes

TABLE 2
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted on 27 May 1994

VAPOR EXTRACTION WELL MW-1E				MONITORING POINTS*	
				VP-6	MW-3
DISTANCE FROM MONITORING POINT TO MW-1E				25 ft.	28 ft.
TEMP. F	ELAPSED TIME (min.)	VACUUM (inches H2O)	FLOW VOLUME (scfm)	INDUCED VACUUM (inches H20)	INDUCED VACUUM (inches H20)
–	START	–	–	–	–
670	15:00	186	37	0.00	0.14
681	30:00	186	39	–	–
–	45:00	–	–	0.08	0.15
669	60:00	189	44	–	–
627	90:00	201	39	0.10	0.16

VAPOR EXTRACTION WELL MW-3				MONITORING POINT*
				MW-4
DISTANCE FROM MONITORING POINT TO MW-3				47 ft.
TEMP. F	ELAPSED TIME (min.)	VACUUM (inches H2O)	FLOW VOLUME (scfm)	INDUCED VACUUM (inches H20)
–	START	–	–	–
504	30:00	166	26	–
569	60:00	196	10	0.14
661	90:00	199	9	0.14

min. = minutes
scfm = standard cubic feet per minute
VP = vapor point
MW = monitoring well
* induced vacuums were not observed at other test monitoring points

APPENDIX B

VAPOR EXTRACTION TEST LETTER REPORT
7 JUNE 1994
(TESTS CONDUCTED ON 4, 5, AND 10 MAY 1994)

Groundwater
& Environmental Services, Inc.

410 Eagleview Boulevard • Suite 110 • Exton, Pennsylvania 19341 • (610) 458-1077 • FAX (610) 458-1081

7 June 1994

Mr. Vernon Butler
Project Coordinator
Region III
United States Environmental Protection Agency
841 Chestnut Building
Philadelphia, Pennsylvania 19107

Re: High-Vacuum Extraction Test Results
Quebecor Printing Atglen Inc.
Corrective Action Consent Order
Docket No. RCRA-3-003IH

Dear Mr. Butler:

The following letter details the results of a series of high-vacuum extraction tests conducted at the above referenced facility on 4 May, 5 May, and 10 May 1994. These tests were performed as part of the Corrective Measures Study being conducted at the site. This letter is being provided, per previous agreement between United States Environmental Protection Agency (USEPA), Quebecor Printing Atglen Inc. (Quebecor), and Groundwater and Environmental Services, Inc. (GES), which stated that the results of pilot tests conducted at the facility would be reported to the USEPA prior to the submittal of the CMS. These test results will also be included with the final CMS.

BACKGROUND

As part of an ongoing remediation study at the Quebecor facility in Atglen, Pennsylvania, GES conducted pilot tests employing high-vacuum extraction to determine the feasibility of this technology as a means of remediation and to determine if groundwater withdrawal can be enhanced by high-vacuum extraction. Tests were conducted by extracting vapors from well RW-2 on 4 May; from well MW-10 on 5 May; and simultaneously from RW-2 and MW-10 on 10 May 1994. Figures 1, 2, and 3 show the well and vapor monitoring point locations used during the tests.

METHODOLOGY

GES utilized a vapor extraction and treatment unit (VR unit) manufactured by Vapor Recovery Systems, Inc.® to conduct the tests. The VR unit is an internal combustion engine capable of extracting vapors from a designated vapor recovery point at a maximum design air flow rate of 250 cubic feet per minute and is capable of producing a vacuum of 244 inches of water.

The vapors withdrawn from the extraction points are pulled back to the VR unit and destroyed in the internal combustion engine. If withdrawn hydrocarbon concentrations are high enough, the recovered vapors can be used as the sole source of fuel to run the engine. The system is completely automated and will supply supplemental fuel (propane) when hydrocarbon concentrations are not sufficient to run the system. The system is capable of removing up to 55 lbs/hr of hydrocarbons at a total destruction rate of 99.97%.

GES also utilized a Thermo Environmental Instruments® Model 580B Photoionization Organic Vapor Meter (OVM) to monitor influent volatile organic compounds (VOC) concentrations during the course of the tests. In addition, an explosimeter was used to monitor the lower explosive limit (LEL) of the influent air stream. An oxygen meter was used to monitor influent oxygen levels.

During each test, induced vacuum was monitored at monitoring wells surrounding the extraction points, or in temporary vapor monitoring points. The temporary monitoring points were constructed by hand-driving a 1/2-inch diameter steel rod approximately 48 inches below grade. After the rod was removed, a 30-inch long, 1/4-inch diameter copper tube was inserted into the hole. A 1-inch diameter rubber stopper, which slides over the tube was installed near the top of the copper tube. When the copper tube is inserted into the soil, the rubber stopper acts as a plug and a vacuum seal. Soil pressure and soil gas can also be monitored through this tube.

During the first test, conducted on 4 May on RW-2, vacuum was monitored at existing wells S-1, S-2, and S-4. This test was conducted near the area where solvent first discharged to the ground surface during the 26 November 1986 solvent spill. During the second test, conducted on 5 May on MW-10, vacuum was monitored at wells MW-19, and MW-20, and in vapor monitoring points VP-1, VP-2, VP-3, and VP-4. Note that wells MW-19 and MW-20 were installed specifically for use during this test. This test was conducted approximately 200 feet down gradient of RW2. Prior to conducting the third test, two additional vapor points (VP-5 and VP-6) were installed (Figure 3). On 10 May, during the third test, vacuum was induced simultaneously on RW-2 and MW-10. During this test, VP5, VP6, and S3 were monitored in addition to the above mentioned points.

On Wednesday, 4 May 1994, a high-vacuum extraction pilot test was conducted on recovery well RW-2 for 4.5 hours. Well RW-2 was outfitted with a specially designed air-tight cap that would enable water removal via a submersible pump at the same time the VR unit was pulling a vacuum on the well. Vacuum gauges were deployed on surrounding wells S-1, S-2, and S-4 to monitor remote vacuum influence at each of these points. The distances to the surrounding wells from RW-2 ranged from 16 to 36 feet. The water pumping rate from RW-2 was also monitored. Vacuum readings and water flow rates were taken and recorded every half hour throughout the test. The tabulated results from this test can be found in Tables 1 and 4. Figure 1 depicts the vacuum influence induced during the test.

On Thursday, 5 May 1994, a four-hour pilot test was conducted on MW-10. This test was set up the same way as the test performed on RW-2. Vacuum gauges were deployed on two surrounding wells, MW-19 and MW-20, and four surrounding vapor points, VP-1, VP-2, VP-3 and VP-4. The distance to these points ranged from 15 to 26.5 feet. Again, vacuum and water flow rates were taken and recorded every half hour throughout the testing period. The tabulated results from this test can be found on Tables 2 and 4. Figure 2 depicts the vacuum influence induced during the test.

On Tuesday, 10 May 1994, a seven and one half-hour pilot test was conducted simultaneously on RW-2 and MW-10. The purpose of this test was to gather additional data specific to operation of two simultaneous withdrawal points. This test was performed in the same manner as the first two tests, except that the VR unit was set up to produce a vacuum on both wells at the same time. All of the monitoring points used to conduct the first two tests were used again along with the two additional vapor points, VP-5 and VP-6, and well S-3. These wells and vapor points were monitored for vacuum influence and the pumping rates of RW-2 and MW-10 were monitored and recorded every half hour. The results of this test can be found on Tables 3 and 4. Figure 3 depicts the range of vacuum influence induced during the test.

During all three tests, vacuum and the air flow readings at the VR unit were monitored and recorded.

The results of all three tests showed that high-vacuum extraction had a measurable influence on the surrounding soils. The first test performed on RW-2 showed elevated vacuum readings in monitoring points S-1 and S-2. The water flow rate from the submersible pump increased from 0.33 gallons per minute (gpm) at the beginning of the test to a maximum of 0.85 gpm before leveling off to a constant flow rate of 0.45 gpm. This increase is attributed to the influence of the vacuum applied to the well. A total of 193 gallons of water was pumped from the well during the test. OVM readings taken during the first hour of the test showed readings between 9 parts per million (ppm) and 16 ppm. Air flow through the VR unit during the test ranged from 45 cubic feet per minute (cfm) to 65 cfm. Lower explosive limits (LELs) were consistently 2% throughout the course of the test.

The results of the second test, performed on MW-10, showed vacuum influence at monitoring points MW-19 and MW-20. The water flow rate from the submersible pump deployed in MW-10 increased from 0.22 gpm to 0.86 gpm, before becoming constant at 0.67 gpm. LELs recorded during this test ranged from 1% to 3%.

A total of 190 gallons was pumped from the well during the test. OVM readings taken during the test ranged from 205 to 345 ppm. Air flow through the VR unit during the test ranged from 22 to 33 cfm.

The results of the third test, conducted simultaneously on RW-2 and MW-10 simultaneously, showed the same or better results than the first two tests. Two additional vapor points, VP-5 and VP-6, were installed at equal distances between RW-2 and MW-10 prior to running the test. During this test, the vacuum influence around both RW-2 and MW-10 increased, as shown on Figure 3. Constant pumping flow rates of 0.44 gpm from RW-2 and 0.60 gpm from MW-10 were achieved. The combined OVM readings ranged from 14 ppm to 50 ppm, and the combined air flow readings ranged from 82 cfm to 104 cfm. LEL readings ranged from 0% to 1%.

On 11 May, after completion of the third test, groundwater samples were collected from wells RW-2 and MW-10 and were analyzed for benzene, toluene, ethylbenzene, and xylene (BTEX) using EPA Method 8020. These results show elevated BTEX levels, greater than 140,000 ppb in MW-10 and greater than 42,000 ppb in RW-2.

CONCLUSIONS

Based on the results of the three high-vacuum extraction pilot tests that were performed, GES has determined this technology is a technically feasible alternative for remediation at the site. GES is currently in the process of designing a site specific extraction and treatment system for the purpose of cost estimation to determine if vapor extraction is an economically feasible option at this site.

The information presented in this letter will be reiterated in the draft Corrective Measures Study (CMS), scheduled to be submitted to EPA on 31 July 1994. If a high-vacuum extraction system is determined to be the best remedial option for this site, a preliminary design for such a system will also be submitted with the CMS.

Should you have any further questions or comments on this material, please do not hesitate to contact me at this office.

Sincerely,

for:

David ~~Veasey~~,
Senior Engineer

Enclosures

cc: Diane Potts - Quebecor
Mark A. Sweitzer - GES
Chris Mulry - GES
Daniel Snowdon - PADER
Kevin Martin - GES
Sharon Roberts - GES

TABLE 1
QUEBECOR VR TEST SUMMARY FROM RW2
QUEBECOR PRINTING ATGLEN INC.

TIME	VR VACUUM H2O	AIR FLOW CFM	VACUUM IN INCHES H20			OVM PPM	LEL %
			S1	S2	S4		
15 min	210	45	0	0	0	9.8	2
30 min	204	48	0	0	0	11.4	2
45 min	209	55	0	0	0	16.2	2
60 min	208	55	0	0	0	*	2
90 min	208	57	0	0	0	*	2
120 min	207	58	0	0	0	*	2
150 min	208	60	0	0	0	*	2
180 min	207	61	0.15	0	0	*	2
210 min	207	63	0.62	0.02	0	*	NR
240 min	208	65	0.2	0.025	0	*	NR
270 min	207	65	0.12	0.01	0	*	NR

* OVM stopped functioning
NR - Not Recorded

TABLE 2
QUEBECOR VR TEST SUMMARY FROM MW10
QUEBECOR PRINTING ATGLEN, INC,

TIME	VR VACUUM H2O	AIR FLOW CFM	VACUUM IN INCHES H20		VACUUM AT MONITORING POINTS					LEL %
			MW19	MW20	VP1	VP2	VP3	VP4	OVM ppm	
15 min	192	22	0.05	0.96	0	0	0	0		
30 min	204	25	0.04	1	0	0	0	0	345	3
45 min	222	32	0.04	1.1	0	0	0	0	319	3
60 min	223	27	0.05	1.1	0	0	0	0	311	2
90 min	222	27	0.01	1.1	0	0	0	0	320	2
120 min	226	28	0	0.5	0	0	0	0	256	1
150 min	223	30	0.04	0.9	0	0	0	0.05	277	
180 min	225	30	0	0.9	0	0	0	0	289	1
210 min	223	30	0	0.8	0	0	0	0.02	276	2
240 min	226	33	0	0.8	0	0	0	0.02	205	1

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TABLE 3
V-R TEST SUMMARY FROM RW2 AND MW10
QUBECOR PRINTING ATGLEN INC

TIME	VR VACUUM H20	AIR FLOW CFM	VACUUM IN INCHES H20										OVM (PPM)	O2 (%)	LEL %
			MW19	MW20	VP2	VP3	VP4	VP5	VP6	S1	S2	S3	S4			
30 min	214	82	0.29	0.90	0.0	0.0	0.0	0.0	0.0	0.2		>20	0.0	14	20.5	0
60 min	209	88	0.36	1.15	0.00	0.0	0.0	0.0	0.06	0.2	0	>20	0.0	44	20.4	1
90 min	205	91	0.44	1.70	0.04	0.0	0.0	0.0	0.0	0.52	0.07	>20	0.02	42	20.4	0
120 min	203	93	0.32	1.70	0.04	0.0	0.0	0.0	0.0	0.75	0.08	>20	0.02			0
180 min	199	95	0.30	1.80	0.04	0.0	0.0	0.0	0.02	>1.0	0.06	>20	0.02	37	20.5	
210 min	196	96	0.30	1.00	0.02	0.0	0.0	0.0	0.0	0.15	0.02	>20	0.03	30	20.6	
240 min	195	98	0.44	1.15	0.02	0.0	0.0	0.0	0.02	1.75	0.03	>20	0.03	32	20.6	0
270 min	193	99	0.45	1.20	0.01	0.0	0.0	0.0	0.02	3.1	0.02	>20	0.02	30	20.7	
300 min	191	100	0.52	1.20	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.02	27	20.8	
330 min	189	101	0.68	1.20	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.02	29	20.8	
360 min	187	103	0.76	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	34	20.8	
390 min	185	103	0.74	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	34	20.8	
420 min	184	103	0.79	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	37	20.8	
450 min	182	104	0.93	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	50	20.8	
480 min	181	98	0.99	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02			50	20.8	

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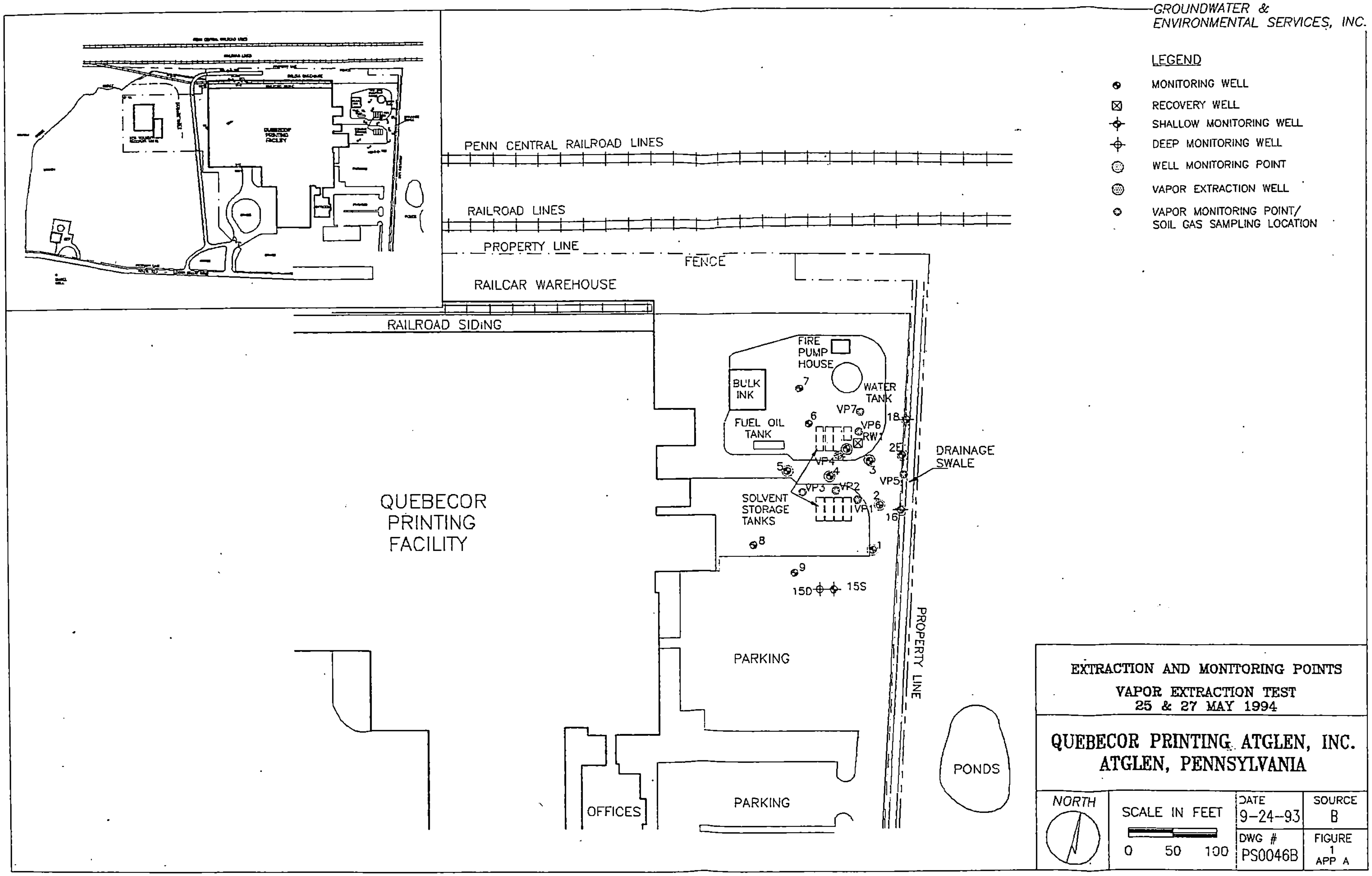
TABLE 4
WATER FLOW RATES
QUEBECOR PRINTING ATGLEN INC.
Summary of results from High-Vacuum Extraction Pilot Tests

DATE	PUMPED WELL (FEET)	FLOW RATE (GPM)	DEPTH TO WATER	WATER LEVEL RISING OR FALLING	ELAPSED PUMPING TIME UNDER VACUUM	VACUUM ON WELL IN H20
4-May-94	RW2	0.33	32.15	Falling	0 min	None
4-May-94	RW2	0.85	NR	Falling	30 min	204
4-May-94	RW2	0.66	NR	Falling	60 min	208
4-May-94	RW2	0.59	NR	Falling	90 min	NR
4-May-94	RW2	0.05	NR	Falling	180 min	207
4-May-94	RW2	0.44	NR	Falling	195 min	207
4-May-94	RW2	0.44	NR	Falling	210 min	207
5-May-94	MW10	0.21	NR	NR	- 20 min	None
5-May-94	MW10	0.2	15.51	Rising	- 10 min	None
5-May-94	MW10	0.22	15.54	Falling	- 5 min	None
5-May-94	MW10	0.75	15.66	Rising	30 min	204
5-May-94	MW10	0.86	13.4	Falling	60 min	223
5-May-94	MW10	0.68	15.46	Rising	90 min	222
5-May-94	MW10	0.67	14.9	Rising	120 min	226
5-May-94	MW10	0.7	14.96	Falling	150 min	223
5-May-94	MW10	0.67	15.6	Rising	180 min	225
5-May-94	MW10	0.67	15.62	Falling	210 min	223
5-May-94	MW10	0.66	15.65	Rising	240 min	226
10-May-94	MW10	0.66	15.2	NR	180 min	196
10-May-94	MW10	0.60	13.65	NR	360 min	185
10-May-94	MW10	0.60	13.75	NR	390 min	184
10-May-94	RW2	0.47	33.27	NR	180 min	196
10-May-94	RW2	0.45	33.4	NR	360 min	185
10-May-94	RW2	0.44	33.0	NR	390 min	184

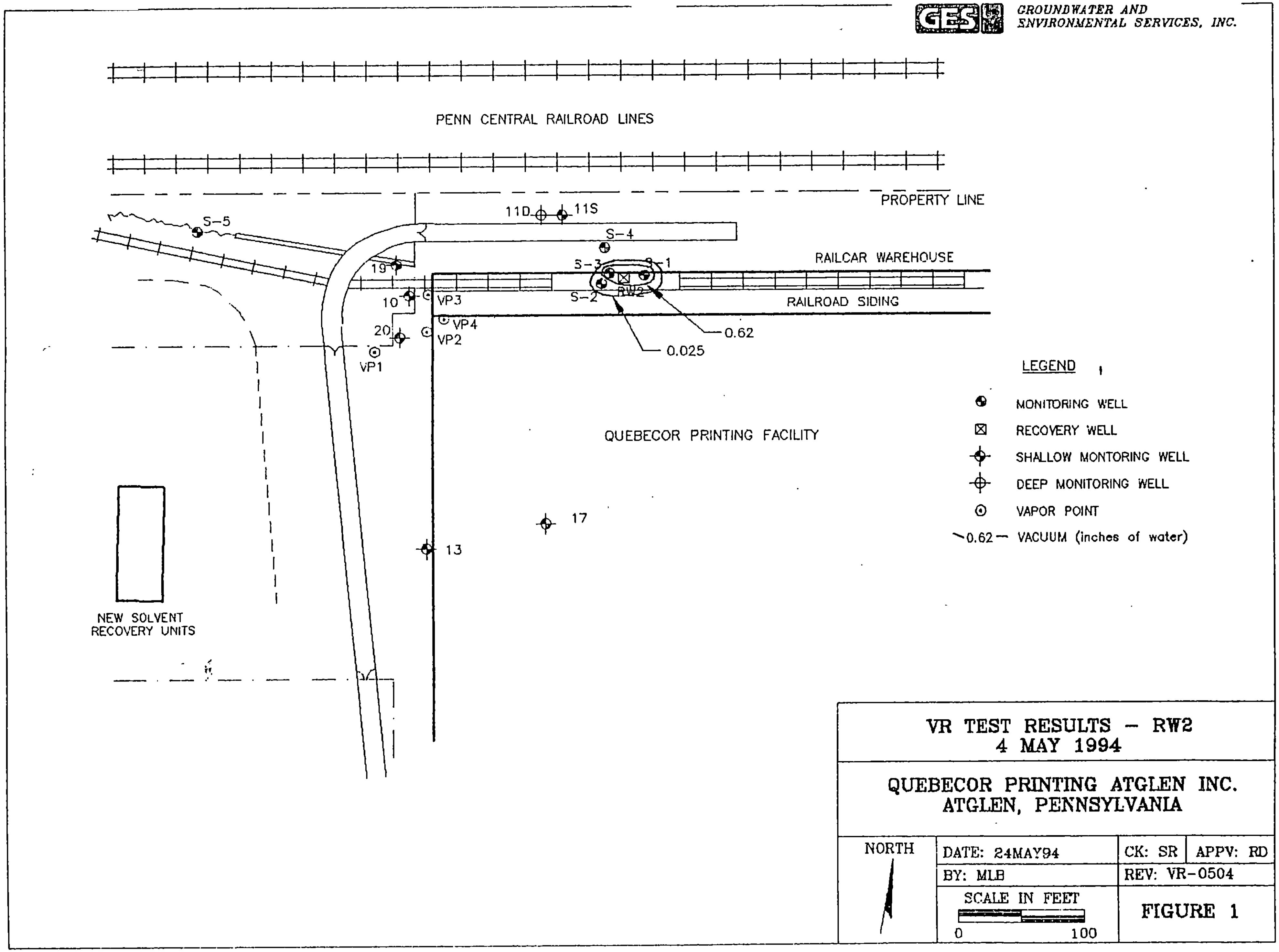
NR - Not recorded



EXTRACTION AND MONITORING POINTS
VAPOR EXTRACTION TEST
25 & 27 MAY 1994

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA

DATE	SOURCE
9-24-93	B
DWG # PS0046B	FIGURE 1 APP A



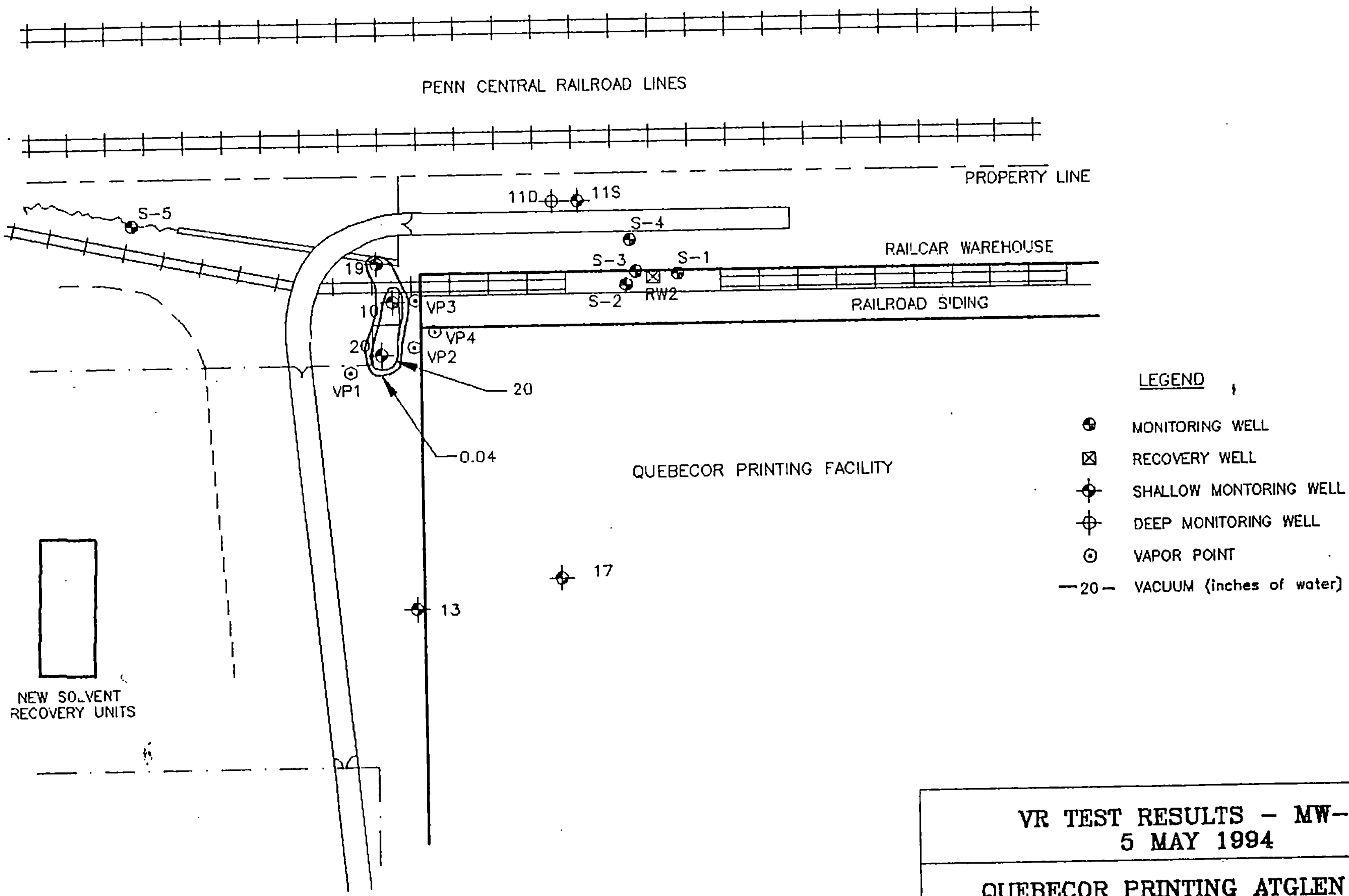
VR TEST RESULTS – RW2
4 MAY 1994

QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

DATE: 24MAY94		CK: SR	APPV: RD
BY: MLB		REV: VR-0504	

FIGURE 1

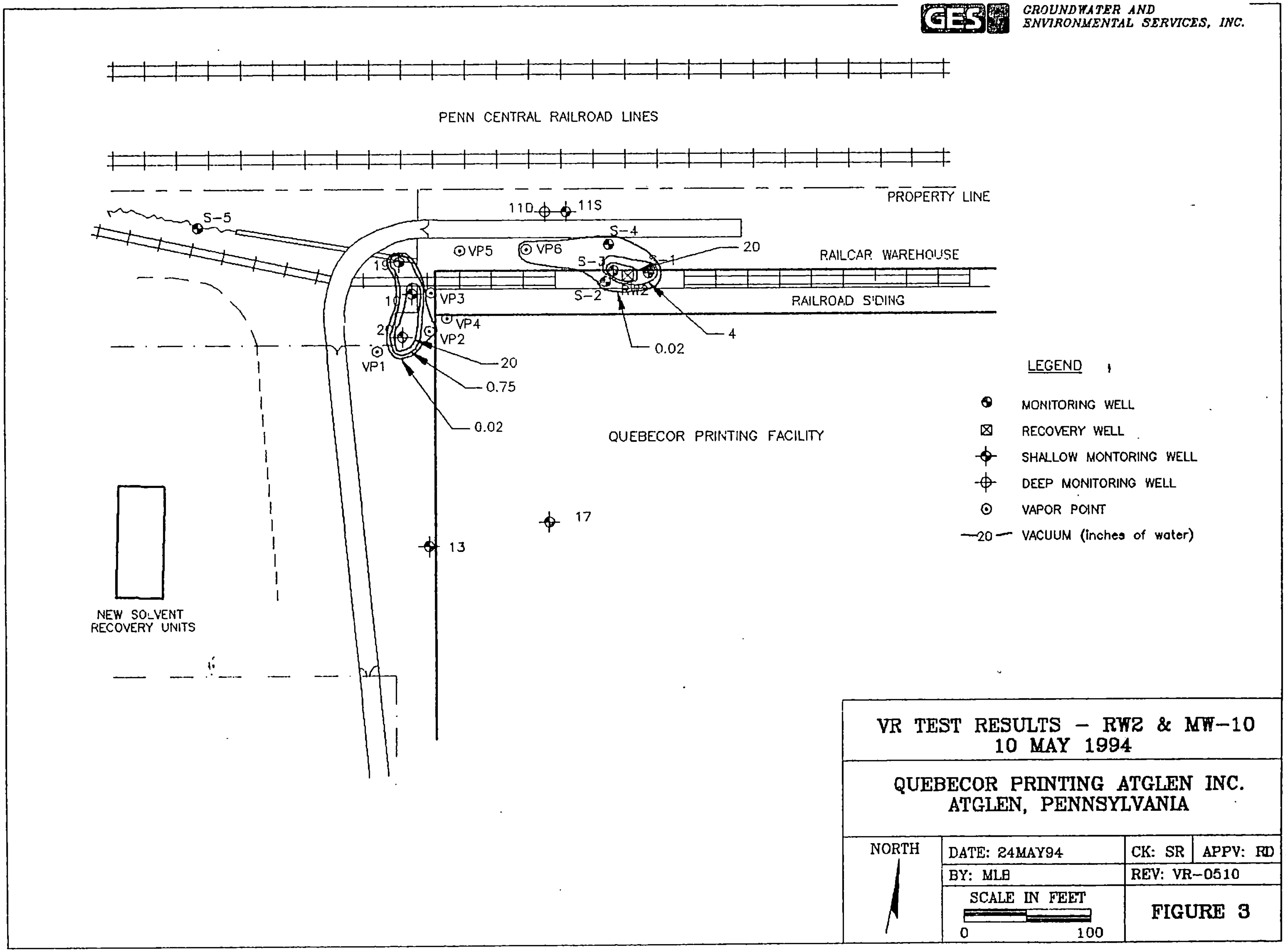
GES GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.



VR TEST RESULTS – MW-10
5 MAY 1994

QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

NORTH	DATE: 24MAY94	CK: SR	APPV: RD
	BY: MLB	REV: VR-0505	
	SCALE IN FEET 0 100	FIGURE 2	


GES
GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.
PENN CENTRAL RAILROAD LINES
PROPERTY LINE
S-5
11D
11S
S-4
VP5
VP6
20
RAILCAR WAREHOUSE
S-3
S-1
S-2
RW2
RAILROAD SIDING
4
0.02
19
10
VP3
VP4
VP2
VP1
20
0.75
0.02
QUEBECOR PRINTING FACILITY
17
13
NEW SOLVENT RECOVERY UNITS
LEGEND
MONITORING WELL
RECOVERY WELL
SHALLOW MONTORING WELL
DEEP MONITORING WELL
VAPOR POINT
20 VACUUM (inches of water)
VR TEST RESULTS - RW2 & MW-10
10 MAY 1994
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA
NORTH
DATE: 24MAY94
CK: SR
APPV: RD
BY: MLB
REV: VR-0510
SCALE IN FEET
0
100
FIGURE 3

APPENDIX B

ADDENDUM TO
VAPOR EXTRACTION TEST LETTER REPORT
7 JUNE 1994
(TESTS CONDUCTED ON 4, 5, AND 10 MAY 1994)

TABLE 1
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

ADDENDUM TO VAPOR EXTRACTION LETTER REPORT OF 7 JUNE 1994:
SUMMARY OF CALCULATIONS

Tests conducted 4, 5 and 10 May 1994

Calculations for determining vapor permeability (k) and radius of influence of SVE points using equations described by P.C. Johnson et al, Groundwater Monitoring Review, Spring 1990.

Determination of soil permeability (k) in darcys:

The governing equation is:

$$k = \frac{Q * u * \ln(Rw/Ro)}{H * pi * Pw[1-(Po/Pw)^2]}$$

Where:
- Q = air flow at the extraction well in cm3/sec
- u = viscosity of air in centipoise (0.018 cp)
- Rw = borehole radius of extraction well in cm
- Ro = distance to observation well in cm
- H = height of unsaturated zone affected by applied vacuum in cm
- Pw = pressure at the extraction well in atmospheres
- Po = pressure at the observation well in atmospheres

The following data are the results of the 10 May 1994 SVE test on MW-10 for MW-20

Q =	33 CFM
u =	0.018 Centipoise
Rw =	0.333 feet
Ro =	21.5 feet
H =	7 feet
Pw (vacuum) =	181 inches-H2O
Po (vacuum) =	1.1 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q =	15574.266 cm3/sec
u =	0.018 Centipoise
Rw =	10.160 cm
Ro =	655.320 cm
H =	213.360 cm
Pw =	0.555 atmospheres
Po =	0.99730 atmospheres

The following data are the results of the 10 May 1994 SVE test on RW-2 for S-2

Q =	65 CFM
u =	0.018 Centipoise
Rw =	0.500 feet
Ro =	15 feet
H =	10 feet
Pw (vacuum) =	181 inches-H2O
Po (vacuum) =	0.02 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q =	30676.584 cm3/sec
u =	0.018 Centipoise
Rw =	15.240 cm
Ro =	464.820 cm
H =	304.800 cm
Pw =	0.555 atmospheres
Po =	0.99995 atmospheres

GES

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted 4, 5 and 10 May 1994

Given the above conditions, the permeability of the formation is:

k =	1.41	darcys	k =	1.58	darcys

Determination of flow rate in CFM/ft:

The governing equation is:

$$Q/H = \frac{K * pi * Pw[1-(Po/Pw)^2]}{u * \ln(Rw/Ro)}$$

Where:
Q/H = air flow per foot of screen at the extraction well in CFM/ft
u = viscosity of air in centipoise (0.018 cp)
Rw = borehole radius of extraction well in cm
Ro = distance to observation well in cm
Pw = pressure at the extraction well in atmospheres
Po = pressure at the observation well in atmospheres

The following data are the results of the 10 May 1994 SVE test on MW-10 for MW-20

K =	1.41	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	22	feet
Pw (vacuum) =	181	inches-H2O
Po (vacuum) =	1.1	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.411	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	655.320	cm
Pw =	0.555	atmospheres
Po =	0.9973	atmospheres

The following data are the results of the 10 May 1994 SVE test on RW-2 for S-2

K =	1.58	darcys
u =	0.018	Centipoise
Rw =	0.500	feet
Ro =	15	feet
Pw (vacuum) =	181	inches-H2O
Po (vacuum) =	0.02	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.583	darcys
u =	0.018	Centipoise
Rw =	15.240	cm
Ro =	464.820	cm
Pw =	0.555	atmospheres
Po =	1.0000	atmospheres

Given the above conditions, the permeability of the formation is:

Q/H =	4.71	CFM/ft	Q/H =	6.50	CFM/ft
epth to Water (H) feet =	7	feet	Depth to Water (H) feet =	10	feet
Flow per Vapor Point is:	33.0	CFM	Flow per Vapor Point is:	65.0	CFM

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted 4, 5 and 10 May 1994

Determination of radius of influence in feet:

The governing equation is:

$$k = \frac{Q/H * u * \ln(Rw/Ri)}{pi * Pw[1-(Patm/Pw)^2]}$$

Solving for Ri:

$$Ri = Rw * EXP(-B)$$

Where:

$$B = \frac{k * pi * Pw[1-(Patm/Pw)^2]}{Q/H * u}$$

Q/H = Vapor flow per unit length of screen (CFM/ft)

The following data are the expected operating conditions of the SVE system based on data from MW-10 and MW-20

Q/H =	4.71 CFM/ft
u =	0.018 Centipoise
Rw =	0.333 feet
k =	1.41 darcy
Pw =	181 inches-H2O
Po =	1.1 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.995 cm3/sec
u =	0.018 Centipoise
Rw =	10.150 cm
k =	1.41 darcy
Pw =	0.555 atmospheres
Po =	0.99730 atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-10) is:

Ri = 21.48 feet

The following data are the expected operating conditions of the SVE system based on data from RW-2 and S-2

Q/H =	6.50 CFM/ft
u =	0.018 Centipoise
Rw =	0.500 feet
k =	1.58 darcy
Pw =	181 inches-H2O
Po =	0.02 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	100.645 cm3/sec
u =	0.018 Centipoise
Rw =	15.240 cm
k =	1.58 darcy
Pw =	0.555 atmospheres
Po =	0.99995 atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (RW-2) is:

Ri = 15.25 feet

GES

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 5 May 1994

Estimated travel time from the boundary of the influence to extraction well MW-10

$$V(r) = \frac{- K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

	Distance		Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.333000	10.149840	---	---	---
r2 =	0.650505	19.827392	V(r2) =	2.532840300	0.13
r3 =	0.968010	29.504945	V(r3) =	1.582202512	0.20
r4 =	1.285515	39.182497	V(r4) =	1.137536034	0.28
r5 =	1.603020	48.860050	V(r5) =	0.882382599	0.36
r6 =	1.920525	58.537602	V(r6) =	0.717835427	0.44
r7 =	2.238030	68.215154	V(r7) =	0.603345274	0.53
r8 =	2.555535	77.892707	V(r8) =	0.519309799	0.61
r9 =	2.873040	87.570259	V(r9) =	0.455129869	0.70
r10 =	3.190545	97.247812	V(r10) =	0.404587863	0.78
r11 =	3.508050	106.925364	V(r11) =	0.363802636	0.87
r12 =	3.825555	116.602916	V(r12) =	0.330229802	0.96
r13 =	4.143060	126.280469	V(r13) =	0.302133788	1.05
r14 =	4.460565	135.958021	V(r14) =	0.278291224	1.14
r15 =	4.778070	145.635574	V(r15) =	0.257815644	1.23

Time = 9.28 seconds
0.15 minutes

GES

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 5 May 1994

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	5.095575	155.313126	V(r16) =	0.240049409	1.32
r17 =	5.413080	164.990678	V(r17) =	0.224494615	1.41
r18 =	5.730585	174.668231	V(r18) =	0.210767555	1.51
r19 =	6.048090	184.345783	V(r19) =	0.198567879	1.60
r20 =	6.683100	203.700888	V(r20) =	0.177844011	1.79
r21 =	8.164790	248.862799	V(r21) =	0.142659032	10.39
r22 =	9.646480	294.024710	V(r22) =	0.118803903	12.47
r23 =	11.128170	339.186622	V(r23) =	0.101605295	14.58
r24 =	12.609860	384.348533	V(r24) =	0.088640133	16.72
r25 =	14.091550	429.510444	V(r25) =	0.078529554	18.87
r26 =	15.573240	474.672355	V(r26) =	0.070432391	21.04
r27 =	17.054930	519.834266	V(r27) =	0.063806990	23.22
r28 =	18.536620	564.996178	V(r28) =	0.058289137	25.42
r29 =	20.018310	610.158089	V(r29) =	0.053625087	27.63
r30 =	21.500000	655.320000	V(r30) =	0.049632747	29.85

delX1 (r2 to r19) =	0.317505	feet	Time =	207.81	seconds
delX2(r20 to r30) =	1.481690	feet		3.62	minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well MW-10

Time = 3.62 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 4 May 1994

Estimated travel time from the boundary of the influence to extraction well RW-2

$$V(r) = \frac{-K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.500000	15.240000	---	---	---
r2 =	0.717500	21.869400	V(r2) =	3.293306096	0.07
r3 =	0.935000	28.498800	V(r3) =	2.365884087	0.09
r4 =	1.152500	35.128200	V(r4) =	1.832044346	0.12
r5 =	1.370000	41.757600	V(r5) =	1.487477977	0.15
r6 =	1.587500	48.387000	V(r6) =	1.247778775	0.17
r7 =	1.805000	55.016400	V(r7) =	1.071964979	0.20
r8 =	2.022500	61.645800	V(r8) =	0.937821531	0.23
r9 =	2.240000	68.275200	V(r9) =	0.832298119	0.26
r10 =	2.457500	74.904600	V(r10) =	0.747242470	0.29
r11 =	2.675000	81.534000	V(r11) =	0.677308592	0.32
r12 =	2.892500	88.163400	V(r12) =	0.618849899	0.35
r13 =	3.110000	94.792800	V(r13) =	0.569296528	0.38
r14 =	3.327500	101.422200	V(r14) =	0.526786989	0.41
r15 =	3.545000	108.051600	V(r15) =	0.489940917	0.44

Time = 3.50 seconds
0.06 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 4 May 1994

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	3.762500	114.681000	V(r16) =	0.457713767	0.48
r17 =	3.980000	121.310400	V(r17) =	0.429301020	0.51
r18 =	4.197500	127.939800	V(r18) =	0.404073302	0.54
r19 =	4.415000	134.569200	V(r19) =	0.381531409	0.57
r20 =	4.850000	147.828000	V(r20) =	0.342976974	0.63
r21 =	5.865000	178.765200	V(r21) =	0.276764875	3.67
r22 =	6.880000	209.702400	V(r22) =	0.231338890	4.39
r23 =	7.895000	240.639600	V(r23) =	0.198326663	5.12
r24 =	8.910000	271.576800	V(r24) =	0.173299912	5.86
r25 =	9.925000	302.514000	V(r25) =	0.153702702	6.60
r26 =	10.940000	333.451200	V(r26) =	0.137959243	7.36
r27 =	11.955000	364.388400	V(r27) =	0.125046560	8.12
r28 =	12.970000	395.325600	V(r28) =	0.114272365	8.88
r29 =	13.985000	426.262800	V(r29) =	0.105151852	9.65
r30 =	15.000000	457.200000	V(r30) =	0.097335646	10.43

delX1 (r2 to r19) = 0.217500 feet Time = 72.79 seconds
delX2(r20 to r30) = 1.015000 feet 1.27 minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well RW-2

Time = 1.27 minutes

APPENDIX F

Slug Test - Tables and Curves

APPENDIX F
TABLE 1
SLUG TEST DATA FOR MW-10
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	249.63	60.00	32.00	281.64
1.20	55.17	304.80	65.00	32.00	281.64
1.40	54.86	304.50	70.00	31.70	281.33
1.60	54.56	304.19	75.00	32.00	281.64
1.80	53.95	303.58	80.00	31.70	281.33
2.00	55.78	305.41	85.00	31.09	280.72
3.00	54.56	304.19	90.00	30.78	280.42
4.00	53.34	302.97	95.00	30.78	280.42
5.00	52.43	302.06	100.00	30.48	280.11
6.00	51.82	301.45	105.00	30.78	280.42
7.00	51.21	300.84	110.00	30.78	280.42
8.00	49.38	299.01	115.00	30.18	279.81
9.00	47.24	296.88	120.00	30.18	279.81
10.00	45.42	295.05	150.00	29.87	279.50
11.00	43.89	293.52	180.00	28.65	278.28
12.00	42.67	292.30	210.00	28.65	278.28
13.00	40.84	290.47	240.00	27.43	277.06
14.00	39.93	289.56	270.00	27.13	276.76
15.00	39.01	288.65	300.00	26.52	276.15
16.00	38.10	287.73	330.00	26.21	275.84
17.00	37.80	287.43	360.00	25.60	275.23
18.00	33.83	283.46	390.00	25.30	274.93
19.00	36.27	285.90	420.00	24.99	274.62
20.00	36.27	285.90	450.00	24.69	274.32
25.00	35.97	285.60	480.00	24.08	273.71
30.00	36.27	285.90	510.00	23.77	273.41
35.00	35.97	285.60	540.00	23.47	273.10
40.00	35.97	285.60	570.00	23.16	272.80
45.00	35.66	285.29	600.00	22.86	272.49
50.00	34.75	284.38	660.00	22.25	271.88
55.00	33.83	283.46	720.00	21.64	271.27
0.00	33.53	283.16	780.00	21.03	270.66
0.00	33.22	282.85	840.00	20.42	270.05
0.00	32.92	282.55	900.00	19.81	269.44
0.00	32.61	282.24	960.00	19.51	269.14
0.00	32.31	281.94	1020.00	18.90	268.53

DTW = Depth to water

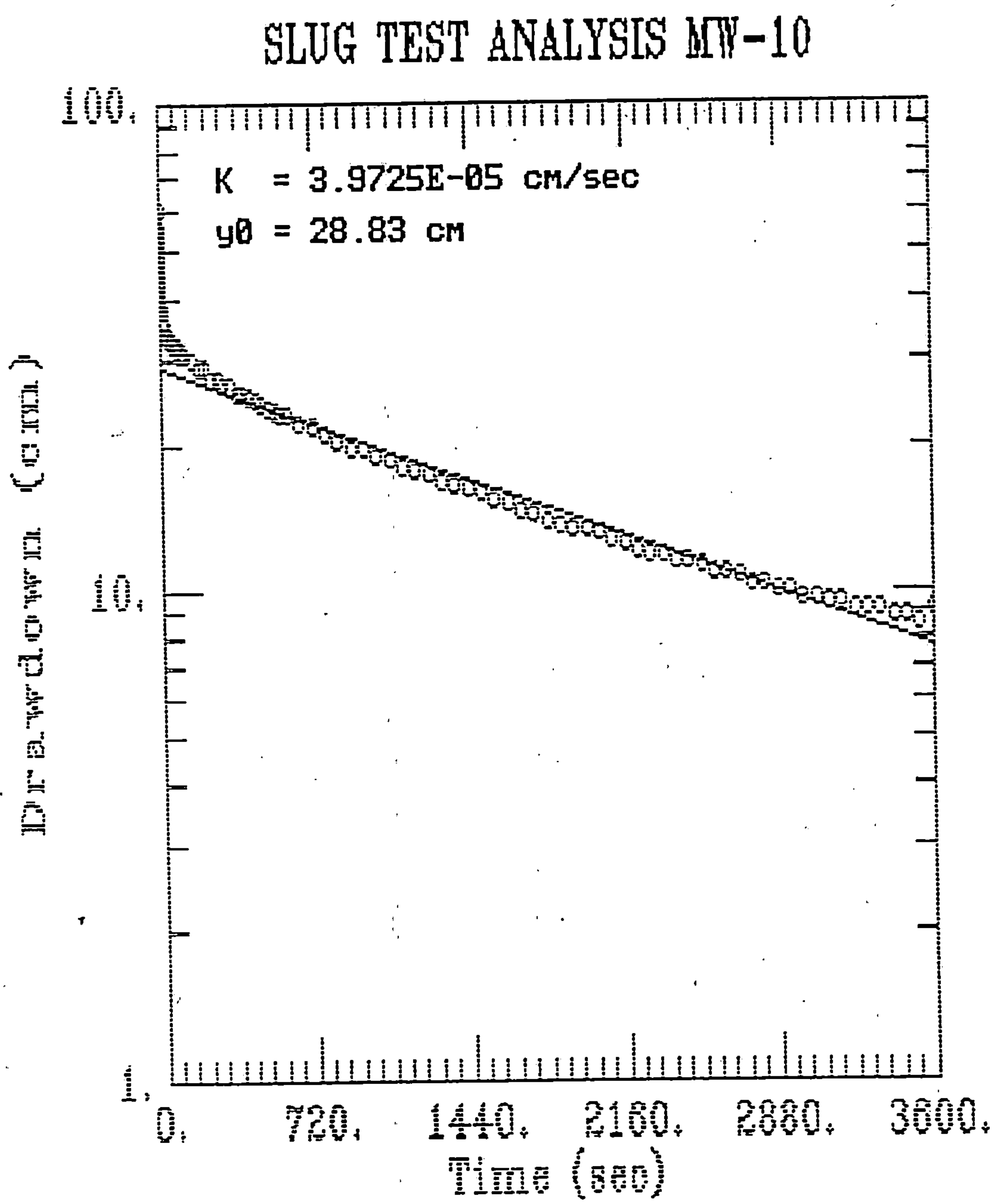
GES

APPENDIX F
TABLE 1
SLUG TEST DATA FOR MW-10 (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	18.59	268.22	2400.00	11.58	261.21
1140.00	17.98	267.61	2460.00	11.58	261.21
1200.00	17.68	267.31	2520.00	11.28	260.91
1260.00	17.37	267.00	2580.00	10.97	260.60
1320.00	16.76	266.40	2640.00	10.97	260.60
1380.00	16.46	266.09	2700.00	10.67	260.30
1440.00	16.15	265.79	2760.00	10.36	259.99
1500.00	15.85	265.48	2820.00	10.36	259.99
1560.00	15.54	265.18	2880.00	10.06	259.69
1620.00	15.24	264.87	2940.00	10.06	259.69
1680.00	14.63	264.26	3000.00	9.75	259.38
1740.00	14.33	263.96	3060.00	9.75	259.38
1800.00	14.02	263.65	3120.00	9.45	259.08
1860.00	13.72	263.35	3180.00	9.45	259.08
1920.00	13.41	263.04	3240.00	9.14	258.78
1980.00	13.41	263.04	3300.00	9.14	258.78
2040.00	13.11	262.74	3360.00	9.14	258.78
2100.00	12.80	262.43	3420.00	8.84	258.47
2160.00	12.50	262.13	3480.00	8.84	258.47
2220.00	12.19	261.82	3540.00	8.53	258.17
2280.00	11.89	261.52	3600.00	9.14	258.78
2340.00	11.89	261.52			

DTW = Depth to water



APPENDIX F
FIGURE 1

APPENDIX F
TABLE 2
SLUG TEST DATA FOR MW-11S
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	281.94	60.00	25.60	307.54
0.20	52.12	334.06	65.00	25.60	307.54
0.40	50.60	332.54	70.00	25.30	307.24
0.59	49.38	331.32	75.00	25.30	307.24
0.80	49.07	331.01	80.00	25.30	307.24
1.00	47.55	329.49	85.00	24.99	306.93
1.20	46.94	328.88	90.00	24.99	306.93
1.40	45.72	327.66	95.00	24.99	306.93
1.60	45.11	327.05	100.00	24.69	306.63
1.80	44.20	326.14	105.00	24.69	306.63
2.00	43.28	325.22	110.00	24.69	306.63
3.00	39.62	321.56	115.00	24.38	306.32
4.00	36.58	318.52	120.00	24.38	306.32
5.00	34.44	316.38	150.00	24.08	306.02
6.00	32.61	314.55	180.00	23.77	305.71
7.00	31.39	313.33	210.00	23.77	305.71
8.00	30.78	312.72	240.00	23.47	305.41
9.00	30.18	312.12	270.00	23.16	305.10
10.00	29.87	311.81	300.00	22.86	304.80
11.00	29.26	311.20	330.00	22.86	304.80
12.00	29.26	311.20	360.00	22.56	304.50
13.00	28.96	310.90	390.00	22.25	304.19
14.00	28.65	310.59	420.00	22.25	304.19
15.00	28.35	310.29	450.00	21.95	303.89
16.00	28.35	310.29	480.00	21.95	303.89
17.00	28.04	309.98	510.00	21.64	303.58
18.00	28.04	309.98	540.00	21.64	303.58
19.00	27.74	309.68	570.00	21.64	303.58
20.00	27.74	309.68	600.00	21.34	303.28
25.00	27.43	309.37	660.00	21.03	302.97
30.00	26.82	308.76	720.00	20.73	302.67
35.00	26.52	308.46	780.00	20.73	302.67
40.00	26.21	308.15	840.00	20.42	302.36
45.00	26.21	308.15	900.00	20.12	302.06
50.00	25.91	307.85	960.00	20.12	302.06
55.00	25.60	307.54	1020.00	19.81	301.75

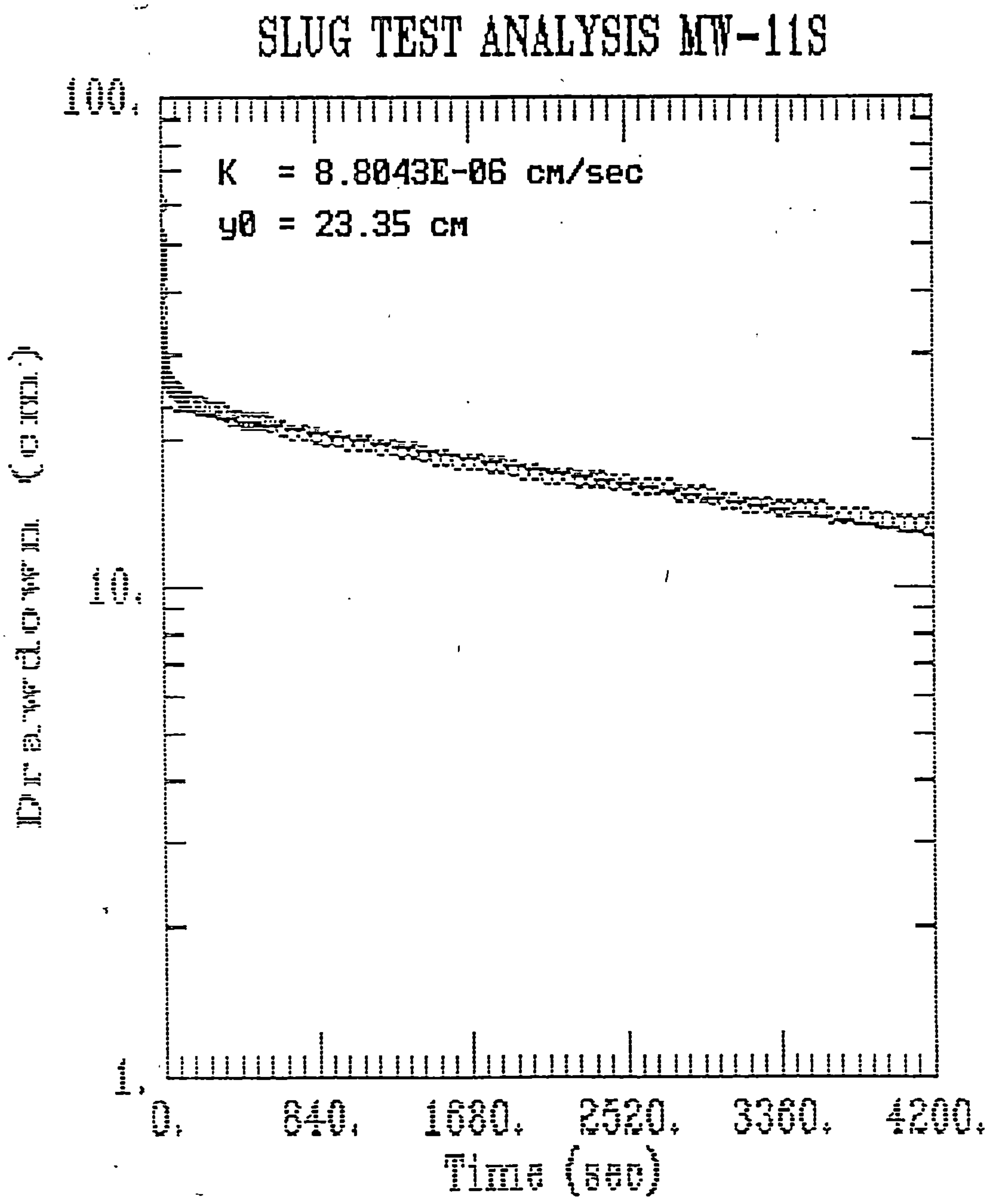
DTW = Depth to water

APPENDIX F
TABLE 2
SLUG TEST DATA FOR MW-11S (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	19.81	301.75	3060.00	14.94	296.88
1140.00	19.51	301.45	3120.00	14.94	296.88
1200.00	19.20	301.14	3180.00	14.63	296.57
1260.00	19.20	301.14	3240.00	14.63	296.57
1320.00	18.90	300.84	3300.00	14.63	296.57
1380.00	18.90	300.84	3360.00	14.33	296.27
1440.00	18.59	300.53	3420.00	14.33	296.27
1500.00	18.29	300.23	3480.00	14.33	296.27
1560.00	18.29	300.23	3540.00	14.33	296.27
1620.00	17.98	299.92	3600.00	14.33	296.27
1680.00	17.98	299.92	3660.00	14.02	295.96
1740.00	17.98	299.92	3720.00	14.02	295.96
1800.00	17.68	299.62	3780.00	14.02	295.96
1860.00	17.68	299.62	3840.00	14.02	295.96
1920.00	17.37	299.31	3900.00	13.72	295.66
1980.00	17.07	299.01	3960.00	13.72	295.66
2040.00	17.07	299.01	4020.00	13.41	295.35
2100.00	16.76	298.70	4080.00	13.41	295.35
2160.00	16.76	298.70	4140.00	13.41	295.35
2220.00	16.76	298.70	4200.00	13.72	295.66
2280.00	16.46	298.40			
2340.00	16.46	298.40			
2400.00	16.46	298.40			
2460.00	16.15	298.09			
2520.00	16.15	298.09			
2580.00	15.85	297.79			
2640.00	15.85	297.79			
2700.00	15.85	297.79			
2760.00	15.85	297.79			
2820.00	15.54	297.48			
2880.00	15.54	297.48			
2940.00	15.54	297.48			
3000.00	15.24	297.18			

DTW = Depth to water



APPENDIX F
FIGURE 2

APPENDIX F
TABLE 3
SLUG TEST DATA FOR MW-12
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	225.55	60.00	7.92	233.48
0.20	61.26	286.82	65.00	7.92	233.48
0.40	52.12	277.67	70.00	7.92	233.48
0.59	47.55	273.10	75.00	7.92	233.48
0.80	45.42	270.97	80.00	7.92	233.48
1.00	43.59	269.14	85.00	7.92	233.48
1.20	41.45	267.00	90.00	7.92	233.48
1.40	39.93	265.48	95.00	7.92	233.48
1.60	38.10	263.65	100.00	7.92	233.48
1.80	36.88	262.43	105.00	7.62	233.17
2.00	35.36	260.91	110.00	7.92	233.48
3.00	28.35	253.90	115.00	7.92	233.48
4.00	22.56	248.11	120.00	7.92	233.48
5.00	17.98	243.54	150.00	7.62	233.17
6.00	14.63	240.18	180.00	7.62	233.17
7.00	12.19	237.74	210.00	7.62	233.17
8.00	10.97	236.52	240.00	7.62	233.17
9.00	10.06	235.61	270.00	7.32	232.87
10.00	9.45	235.00	300.00	7.32	232.87
11.00	9.14	234.70	330.00	7.32	232.87
12.00	8.84	234.39	360.00	7.32	232.87
13.00	8.84	234.39	390.00	7.32	232.87
14.00	8.53	234.09	420.00	7.32	232.87
15.00	8.53	234.09	450.00	7.01	232.56
16.00	8.53	234.09	480.00	7.01	232.56
17.00	8.53	234.09	510.00	7.01	232.56
18.00	8.53	234.09	540.00	7.01	232.56
19.00	8.53	234.09	570.00	7.01	232.56
20.00	8.53	234.09	600.00	7.01	232.56
25.00	8.53	234.09	660.00	7.01	232.56
30.00	8.23	233.78	720.00	6.71	232.26
35.00	8.23	233.78	780.00	6.71	232.26
40.00	8.23	233.78	840.00	6.71	232.26
45.00	8.23	233.78	900.00	6.71	232.26
50.00	8.23	233.78	960.00	6.71	232.26
55.00	8.23	233.78	1020.00	6.40	231.95

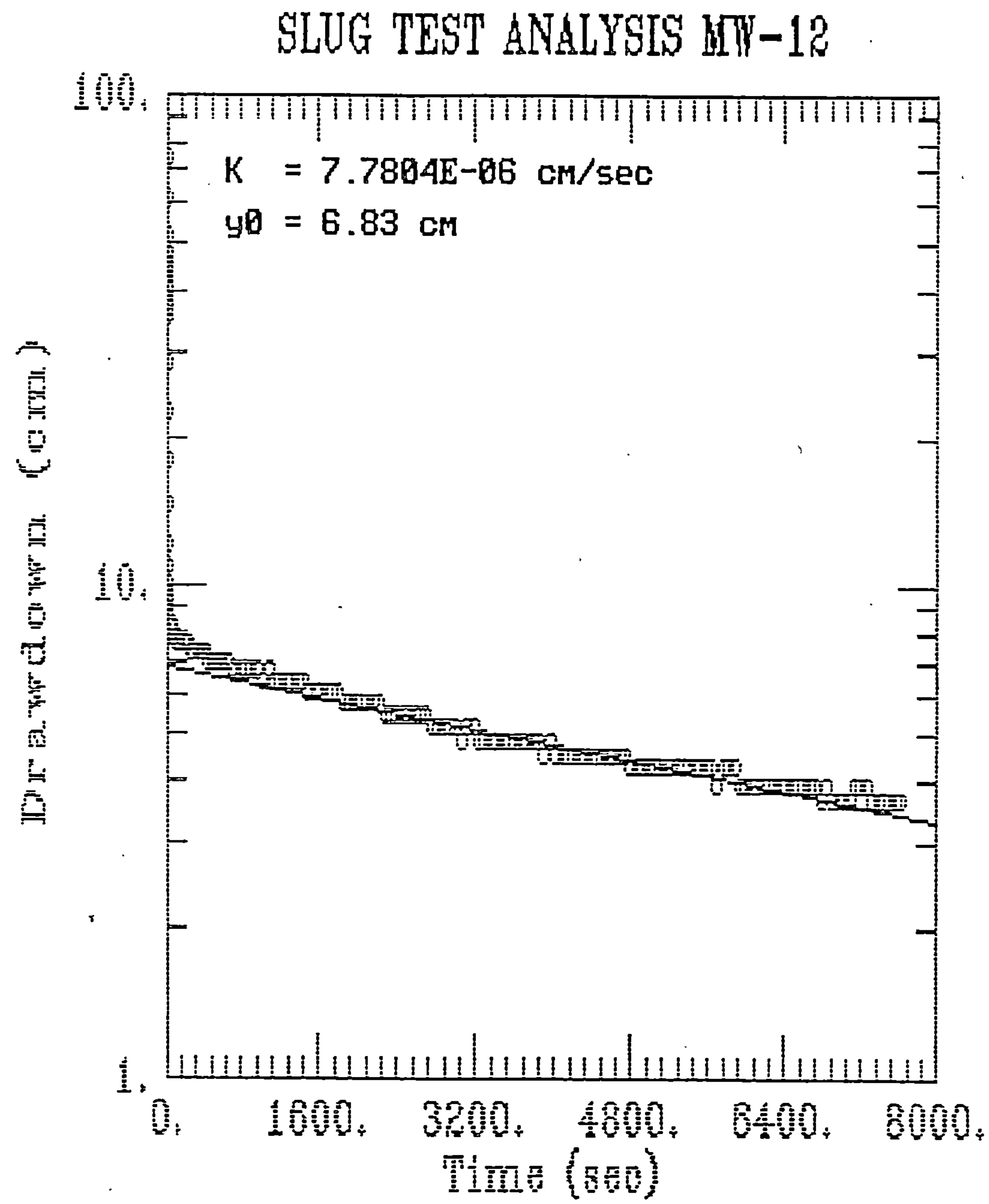
DTW = Depth to water

APPENDIX F
TABLE 3
SLUG TEST DATA FOR MW-12 (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	6.71	232.26	3060.00	4.88	230.43
1140.00	6.40	231.95	3120.00	5.18	230.73
1200.00	6.40	231.95	3180.00	5.18	230.73
1260.00	6.40	231.95	3240.00	4.88	230.43
1320.00	6.40	231.95	3300.00	4.88	230.43
1380.00	6.40	231.95	3360.00	4.88	230.43
1440.00	6.40	231.95	3420.00	4.88	230.43
1500.00	6.10	231.65	3480.00	4.88	230.43
1560.00	6.10	231.65	3540.00	4.88	230.43
1620.00	6.10	231.65	3600.00	4.88	230.43
1680.00	6.10	231.65	3660.00	4.88	230.43
1740.00	6.10	231.65	3720.00	4.88	230.43
1800.00	6.10	231.65	3780.00	4.88	230.43
1860.00	5.79	231.34	3840.00	4.88	230.43
1920.00	5.79	231.34	3900.00	4.57	230.12
1980.00	5.79	231.34	3960.00	4.88	230.43
2040.00	5.79	231.34	4020.00	4.57	230.12
2100.00	5.79	231.34	4080.00	4.57	230.12
2160.00	5.79	231.34	4140.00	4.57	230.12
2220.00	5.79	231.34	4200.00	4.57	230.12
2280.00	5.49	231.04	4260.00	4.57	230.12
2340.00	5.49	231.04	4320.00	4.57	230.12
2400.00	5.49	231.04	4380.00	4.57	230.12
2460.00	5.49	231.04	4440.00	4.57	230.12
2520.00	5.49	231.04	4500.00	4.57	230.12
2580.00	5.49	231.04	5100.00	4.27	229.82
2640.00	5.49	231.04	5700.00	3.96	229.51
2700.00	5.49	231.04	6300.00	3.96	229.51
2760.00	5.18	230.73	6900.00	3.66	229.21
2820.00	5.18	230.73	7500.00	3.66	229.21
2880.00	5.18	230.73			
2940.00	5.18	230.73			
3000.00	5.18	230.73			

DTW = Depth to water



APPENDIX F
FIGURE 3

APPENDIX F
TABLE 4
SLUG TEST DATA FOR MW-14S
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	215.19	60.00	32.00	247.19
0.20	59.74	274.93	65.00	31.70	246.89
0.40	59.13	274.32	70.00	31.39	246.58
0.59	58.52	273.71	75.00	31.09	246.28
0.80	57.91	273.10	80.00	30.78	245.97
1.00	57.30	272.49	85.00	30.48	245.67
1.20	57.30	272.49	90.00	30.48	245.67
1.40	56.69	271.88	95.00	30.18	245.36
1.60	56.08	271.27	100.00	29.87	245.06
1.80	55.78	270.97	105.00	29.87	245.06
2.00	55.17	270.36	110.00	29.57	244.75
3.00	53.34	268.53	115.00	29.26	244.45
4.00	51.51	266.70	120.00	28.96	244.14
5.00	49.68	264.87	150.00	28.04	243.23
6.00	48.16	263.35	180.00	26.82	242.01
7.00	46.63	261.82	210.00	26.21	241.40
8.00	45.11	260.30	240.00	25.30	240.49
9.00	43.89	259.08	270.00	24.38	239.57
10.00	42.67	257.86	300.00	23.77	238.96
11.00	41.45	256.64	330.00	23.16	238.35
12.00	40.54	255.73	360.00	22.56	237.74
13.00	39.62	254.81	390.00	21.95	237.13
14.00	39.01	254.20	420.00	21.64	236.83
15.00	38.40	253.59	450.00	21.03	236.22
16.00	37.80	252.98	480.00	20.42	235.61
17.00	37.49	252.68	510.00	20.12	235.31
18.00	37.19	252.37	540.00	19.51	234.70
19.00	36.88	252.07	570.00	19.20	234.39
20.00	36.58	251.76	600.00	18.90	234.09
25.00	35.66	250.85	660.00	17.68	232.87
30.00	34.75	249.94	720.00	17.07	232.26
35.00	34.14	249.33	780.00	16.46	231.65
40.00	33.53	248.72	840.00	15.85	231.04
45.00	33.22	248.41	900.00	15.24	230.43
50.00	32.92	248.11	960.00	14.63	229.82
55.00	32.31	247.50	1020.00	14.33	229.51

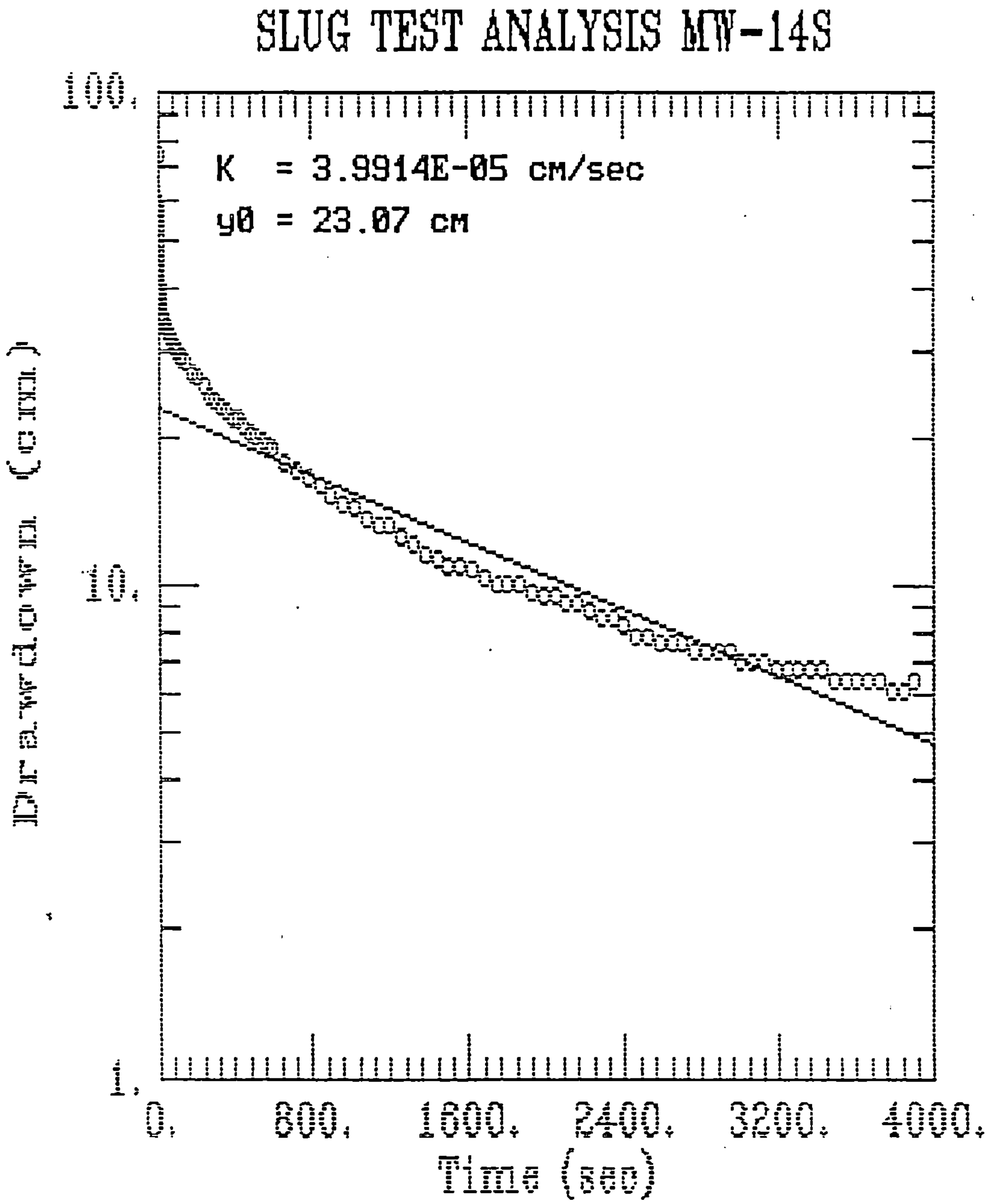
DTW = Depth to water

APPENDIX F
TABLE 4
SLUG TEST DATA FOR MW-14S (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	13.72	228.90	3060.00	7.01	222.20
1140.00	13.11	228.30	3120.00	7.01	222.20
1200.00	13.11	228.30	3180.00	6.71	221.89
1260.00	12.50	227.69	3240.00	6.71	221.89
1320.00	12.19	227.38	3300.00	6.71	221.89
1380.00	11.58	226.77	3360.00	6.71	221.89
1440.00	11.28	226.47	3420.00	6.71	221.89
1500.00	10.97	226.16	3480.00	6.40	221.59
1560.00	10.97	226.16	3540.00	6.40	221.59
1620.00	10.67	225.86	3600.00	6.40	221.59
1680.00	10.36	225.55	3660.00	6.40	221.59
1740.00	10.06	225.25	3720.00	6.40	221.59
1800.00	10.06	225.25	3780.00	6.10	221.28
1860.00	10.06	225.25	3840.00	6.10	221.28
1920.00	9.75	224.94	3900.00	6.40	221.59
1980.00	9.45	224.64			
2040.00	9.45	224.64			
2100.00	9.14	224.33			
2160.00	9.14	224.33			
2220.00	8.84	224.03			
2280.00	8.53	223.72			
2340.00	8.53	223.72			
2400.00	8.23	223.42			
2460.00	7.92	223.11			
2520.00	7.92	223.11			
2580.00	7.62	222.81			
2640.00	7.62	222.81			
2700.00	7.62	222.81			
2760.00	7.32	222.50			
2820.00	7.32	222.50			
2880.00	7.32	222.50			
2940.00	7.32	222.50			
3000.00	7.01	222.20			

DTW = Depth to water



APPENDIX F
FIGURE 4

GES

APPENDIX F
TABLE 5
SLUG TEST DATA FOR MW-15S
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	160.93	60.00	17.68	178.61
0.20	49.38	210.31	65.00	17.68	178.61
0.40	48.46	209.40	70.00	17.68	178.61
0.59	47.55	208.48	75.00	17.68	178.61
0.80	46.63	207.57	80.00	17.68	178.61
1.00	46.02	206.96	85.00	17.68	178.61
1.20	45.11	206.04	90.00	17.68	178.61
1.40	44.50	205.44	95.00	17.37	178.31
1.60	43.89	204.83	100.00	17.37	178.31
1.80	42.98	203.91	105.00	17.37	178.31
2.00	42.37	203.30	110.00	17.37	178.31
3.00	39.01	199.95	115.00	17.37	178.31
4.00	35.97	196.90	120.00	17.37	178.31
5.00	33.53	194.46	150.00	17.07	178.00
6.00	31.09	192.02	180.00	16.76	177.70
7.00	29.26	190.20	210.00	16.46	177.39
8.00	27.43	188.37	240.00	16.15	177.09
9.00	26.21	187.15	270.00	16.15	177.09
10.00	24.99	185.93	300.00	15.85	176.78
11.00	23.77	184.71	330.00	15.85	176.78
12.00	23.16	184.10	360.00	15.54	176.48
13.00	22.25	183.18	390.00	15.54	176.48
14.00	21.64	182.58	420.00	15.24	176.17
15.00	21.34	182.27	450.00	15.24	176.17
16.00	21.03	181.97	480.00	14.94	175.87
17.00	20.73	181.66	510.00	14.94	175.87
18.00	20.42	181.36	540.00	14.63	175.56
19.00	20.12	181.05	570.00	14.33	175.26
20.00	19.81	180.75	600.00	14.33	175.26
25.00	19.20	180.14	660.00	14.02	174.96
30.00	18.90	179.83	720.00	14.02	174.96
35.00	18.59	179.53	780.00	13.72	174.65
40.00	18.29	179.22	840.00	13.41	174.35
45.00	18.29	179.22	900.00	13.41	174.35
50.00	17.98	178.92	960.00	12.80	173.74
55.00	17.98	178.92	1020.00	12.80	173.74

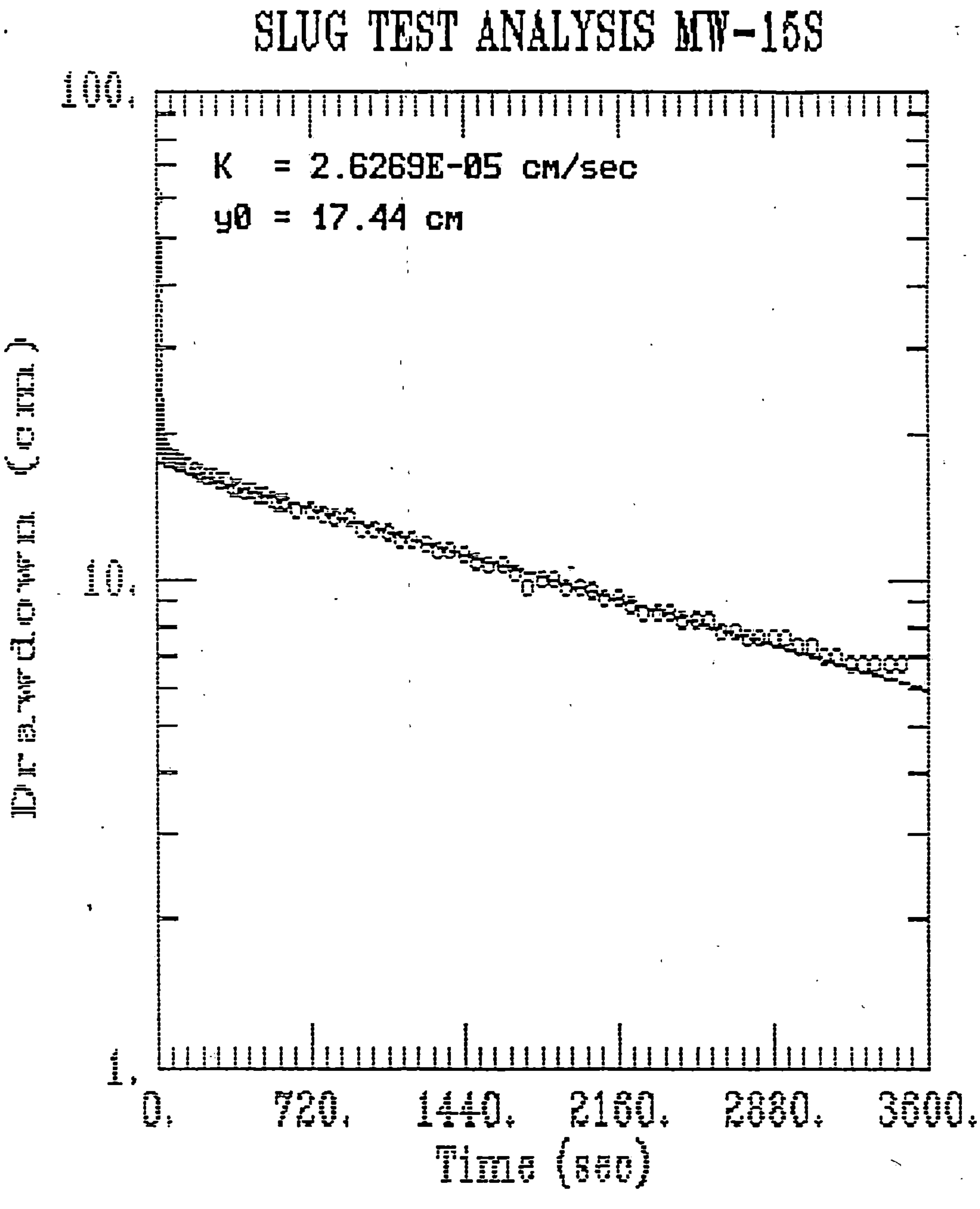
DTW = Depth to water

APPENDIX F
TABLE 5
SLUG TEST DATA FOR MW-15S (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	12.50	173.43	3060.00	7.32	168.25
1140.00	12.19	173.13	3120.00	7.01	167.94
1200.00	12.19	173.13	3180.00	7.01	167.94
1260.00	11.89	172.82	3240.00	6.71	167.64
1320.00	11.58	172.52	3300.00	6.71	167.64
1380.00	11.58	172.52	3360.00	6.71	167.64
1440.00	11.28	172.21	3420.00	6.71	167.64
1500.00	10.97	171.91	3480.00	6.71	167.64
1560.00	-251.76	-90.83			
1620.00	-251.76	-90.83			
1680.00	-251.76	-90.83			
1740.00	-251.76	-90.83			
1800.00	-251.76	-90.83			
1860.00	-251.76	-90.83			
1920.00	-251.76	-90.83			
1980.00	-251.76	-90.83			
2040.00	-251.76	-90.83			
2100.00	-251.76	-90.83			
2160.00	-251.76	-90.83			
2220.00	-251.76	-90.83			
2280.00	-251.76	-90.83			
2340.00	-251.76	-90.83			
2400.00	-251.76	-90.83			
2460.00	-251.76	-90.83			
2520.00	-251.76	-90.83			
2580.00	-251.76	-90.83			
2640.00	-251.76	-90.83			
2700.00	-251.76	-90.83			
2760.00	-251.76	-90.83			
2820.00	-251.76	-90.83			
2880.00	-251.76	-90.83			
2940.00	-251.76	-90.83			
3000.00	-251.76	-90.83			

DTW = Depth to water



APPENDIX F
FIGURE 5

GES

APPENDIX F
TABLE 6
SLUG TEST DATA FOR MW-17
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
0.00	0.00	326.75	60.00	23.16	349.91
0.20	45.72	372.47	65.00	23.16	349.91
0.40	45.11	371.86	70.00	22.86	349.61
0.59	43.89	370.64	75.00	22.86	349.61
0.80	43.28	370.03	80.00	22.86	349.61
1.00	42.37	369.11	85.00	22.86	349.61
1.20	41.45	368.20	90.00	22.56	349.30
1.40	40.54	367.28	95.00	22.56	349.30
1.60	39.93	366.67	100.00	22.56	349.30
1.80	39.01	365.76	105.00	22.56	349.30
2.00	38.10	364.85	110.00	22.56	349.30
3.00	46.02	372.77	115.00	22.25	349.00
4.00	32.31	359.05	120.00	22.25	349.00
5.00	29.87	356.62	150.00	22.25	349.00
6.00	28.65	355.40	180.00	21.95	348.69
7.00	28.04	354.79	210.00	21.95	348.69
8.00	27.43	354.18	240.00	21.95	348.69
9.00	26.82	353.57	270.00	21.64	348.39
10.00	26.52	353.26	300.00	21.64	348.39
11.00	26.21	352.96	330.00	21.64	348.39
12.00	25.91	352.65	360.00	21.64	348.39
13.00	25.91	352.65	390.00	21.64	348.39
14.00	25.60	352.35	420.00	21.64	348.39
15.00	25.30	352.04	450.00	21.34	348.08
16.00	25.30	352.04	480.00	21.34	348.08
17.00	24.99	351.74	510.00	21.34	348.08
18.00	24.99	351.74	540.00	21.34	348.08
19.00	24.99	351.74	570.00	21.34	348.08
20.00	24.69	351.43	600.00	21.34	348.08
25.00	24.38	351.13	660.00	21.34	348.08
30.00	24.08	350.82	720.00	21.34	348.08
35.00	23.77	350.52	780.00	21.34	348.08
40.00	23.47	350.22	840.00	21.64	348.39
45.00	23.47	350.22	900.00	21.34	348.08
50.00	23.16	349.91	960.00	21.34	348.08
55.00	23.16	349.91	1020.00	21.34	348.08

DTW = Depth to water

GES

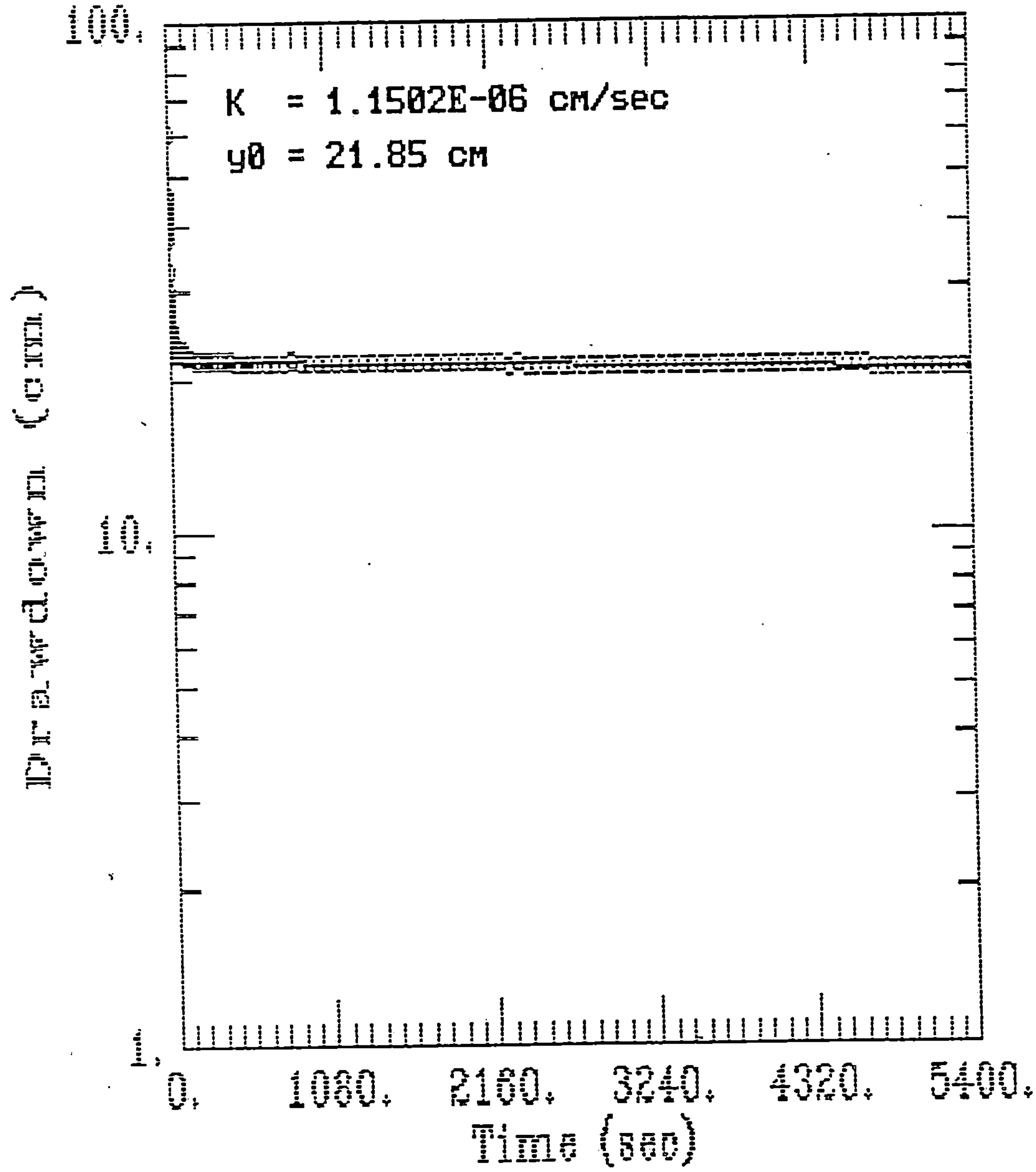
APPENDIX F
TABLE 6
SLUG TEST DATA FOR MW-17 (CONT.)
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

JULY 8, 1993

Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)	Elapsed Time (seconds)	Change in Elevation (cm)	DTW (cm)
1080.00	21.34	348.08	3060.00	21.03	347.78
1140.00	21.34	348.08	3120.00	21.03	347.78
1200.00	21.34	348.08	3180.00	21.03	347.78
1260.00	21.34	348.08	3240.00	21.03	347.78
1320.00	21.34	348.08	3300.00	21.03	347.78
1380.00	21.34	348.08	3360.00	21.03	347.78
1440.00	21.34	348.08	3420.00	21.03	347.78
1500.00	21.34	348.08	3480.00	21.03	347.78
1560.00	21.34	348.08	3540.00	21.03	347.78
1620.00	21.34	348.08	3600.00	21.03	347.78
1680.00	21.34	348.08	3660.00	21.03	347.78
1740.00	21.34	348.08	3720.00	21.03	347.78
1800.00	21.34	348.08	3780.00	21.03	347.78
1860.00	21.34	348.08	3840.00	21.03	347.78
1920.00	21.34	348.08	3900.00	21.03	347.78
1980.00	21.34	348.08	4200.00	21.03	347.78
2040.00	21.34	348.08	4500.00	21.03	347.78
2100.00	21.34	348.08	4800.00	20.73	347.47
2160.00	21.34	348.08	5100.00	20.73	347.47
2220.00	21.34	348.08	5400.00	20.73	347.47
2280.00	21.03	347.78			
2340.00	21.34	348.08			
2400.00	21.03	347.78			
2460.00	21.03	347.78			
2520.00	21.03	347.78			
2580.00	21.03	347.78			
2640.00	21.03	347.78			
2700.00	21.03	347.78			
2760.00	21.03	347.78			
2820.00	21.03	347.78			
2880.00	21.03	347.78			
2940.00	21.03	347.78			
3000.00	21.03	347.78			

DTW = Depth to water

SLUG TEST ANALYSIS MW-17



APPENDIX F
FIGURE 6